UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION
SEPTEMBER 2014 SESSION

SUBJECT CODE	:	**FAB30803**
SUBJECT TITLE	:	**CONTROL SYSTEM**
LEVEL	:	**BACHELOR**
TIME / DURATION	:	**9.00 AM – 12.00 PM** **(3 HOURS)**
DATE	:	**31 DECEMBER 2014**

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.

2. This question paper is printed on both sides of the paper.

3. Please write your answers on the answer booklet provided.

4. Answer should be written in blue or black ink except for sketching, graphic and illustration.

5. This question paper consists of SIX (6) questions. Each question worth 20 marks. Answer FIVE (5) questions only.

6. Answer all questions in English.

7. The semi-log paper, Nichol's chart, graph paper and formula are appended.

**THERE ARE 6 PAGES OF QUESTIONS AND 1 PAGE OF APPENDIX, EXCLUDING THIS PAGE.**

INSTRUCTION: Answer FIVE (5) questions only.

Question 1

(a)   Give **three** (3) objectives of control system design and analysis.

(3 marks)

(b)   Draw a block diagram of the components for elevator-position control system.

(5 marks)

(c)   The schematic diagram for a speed control system is shown in **Figure 1** in which the DC motor voltage *Eg(s)* is generated by a DC generator driven by a prime mover. This system has been used on locomotives where the prime mover is a diesel engine that operates most efficiently at one speed. The motor voltage *Eg(s)* is varied by changing the generator input voltage *E(s)*. Draw all subsystem block diagram and obtain the transfer function $\dfrac{\omega(s)}{E(s)}$ of the system. Assume the following for the system constants:

(12 marks)

|	
E = speed reference voltage	T = output torque
R_f = generator field winding resistance	ω = output speed
L_f = generator field winding inductance	J = *motor and load moment of*
I_f = generator winding current	*inertia*
E_g = generator output voltage/armature winding input voltage	D = load and motor viscous friction coefficient
I_a = armature winding current	K_g = generator constant
R_a = armature winding resistance	K_b = back emf constant
L_a = armature winding inductance	K_m = motor torque constant
V_b = back emf voltage	
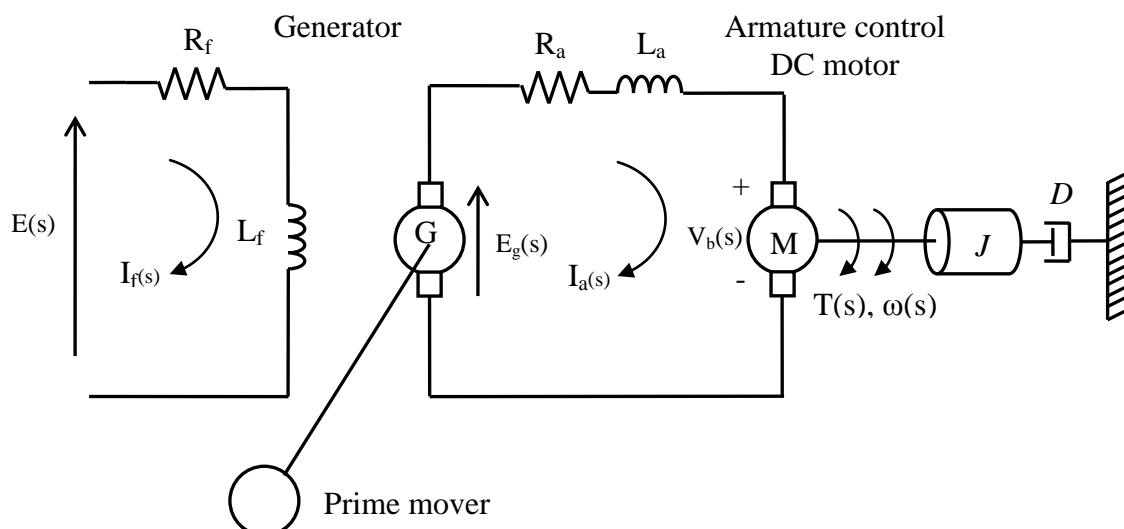
Figure 1: Schematic diagram for a speed control system

Question 2

(a)   Find the transfer function, $\dfrac{C(s)}{R(s)}$ for a block diagram of a system in **Figure 2** by using

the block diagram reduction method.

(10 marks)
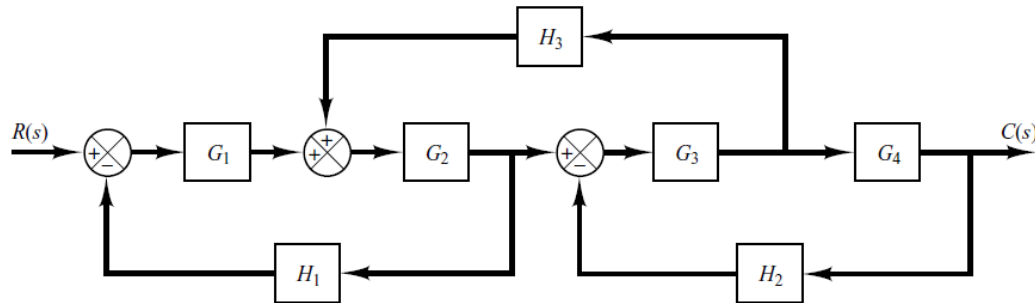
Figure 2: A block diagram of a system

(b)   **Figure 3** shows a block diagram of a servo system. Answer the following questions:

i.   Determine the values of gain K and velocity feedback constant K_h so that the maximum overshoot in the unit-step response is 0.2 and the peak time is 1 second. Assume $J = 1$kg-m^2 and $B = 1$N-m/rad/sec.

(8 marks)

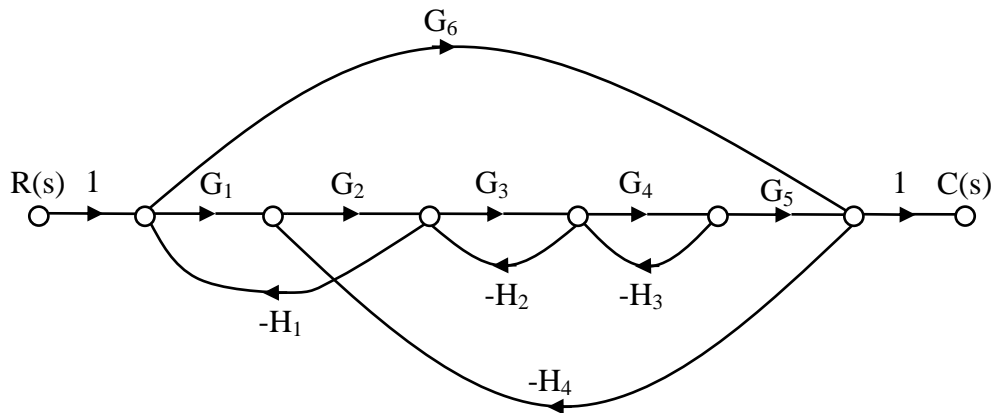ii.   Determine the settling time (T_s) for 2% criterion.

(2 marks)
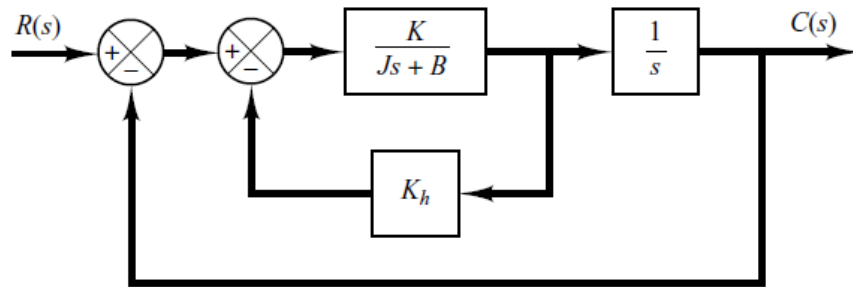
Figure 3: The block diagram of a servo system

Question 3

(a)   **Figure 4** shows a signal flow graph of a system. Obtain the overall transfer function,
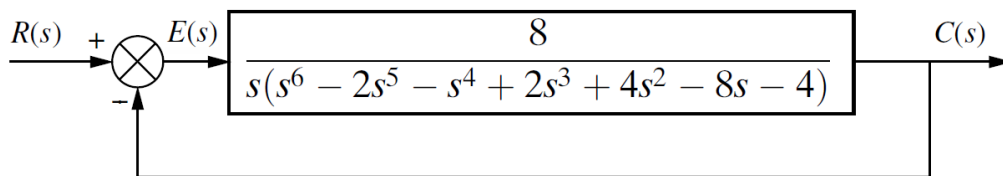
$\dfrac{C(s)}{R(s)}$ of the system.

(10 marks)

Figure 4: A signal flow graph

(b)   Referring to a unity feedback system shown in **Figure 5**, find the number of closed-loop poles located in the right half-plane, left half-plane, and on the jω-axis by using Routh-Hurwitz criterion and comment on the system stability.

(10 marks)
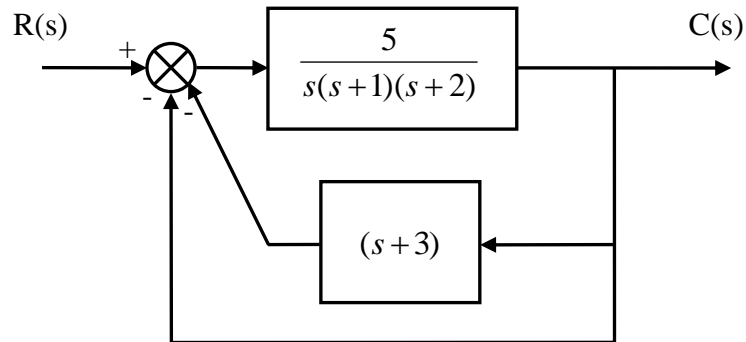

Figure 5: A unity feedback system

Question 4

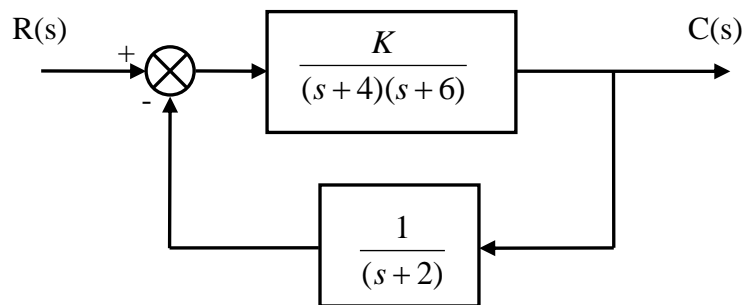(a)   Consider the block diagram of a system shown in **Figure 6**.

R(s)   C(s)

$$\frac{5}{s(s+1)(s+2)}$$

$$(s+3)$$

Figure 6: The block diagram of a system

  i.   Determine the system type.

(3 marks)

  ii.   Find the static error constants of K_p, K_v and K_a.

(3 marks)

  iii.   Obtain the steady state error for an input of $50u(t)$, $50tu(t)$, and $50t^2u(t)$.

(3 marks)

(b)   Consider a non-unity feedback system shown in **Figure 7**.

R(s)   C(s)

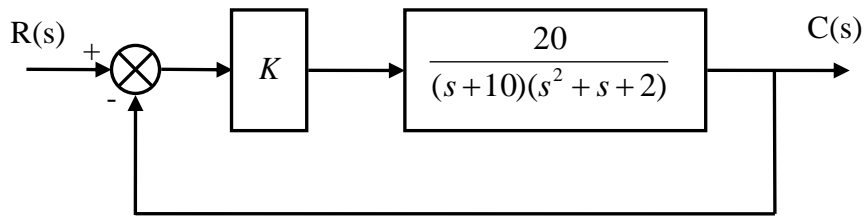$$\frac{K}{(s+4)(s+6)}$$

$$\frac{1}{(s+2)}$$

Figure 7: A non-unity feedback system

        Using the Nyquist criterion, obtain the followings:

  i.   For $K=1$, sketch the Nyquist plot of $G(j\omega)$ for $0<\omega<\infty$

(7 marks)

  ii.   Determine the range of K for stability.

(2 marks)

  iii.   Obtain the gain margin for $K = 300$.

(2 marks)

Question 5

(a) The block diagram of an electric carrier steering control system is shown in **Figure 8**.

Figure 8: An electric carrier steering control system

i. For $K = 3.2$ plot the asymptotic Bode plot for the steering control system.

(8 marks)

ii. From the Bode plot, determine the gain margin (*GM*), phase margin (*PM*), gain cross over frequency (ω_{gco}) and phase cross over frequency (ω_{pco}). Hence, draw a conclusion on the stability of the system.

(4 marks)

(b) Complete **Table 1** from the obtained Bode plot in **Question 5(a)i** and plot the locus of $G(j\omega)$ on a Nichol's chart.

Table 1

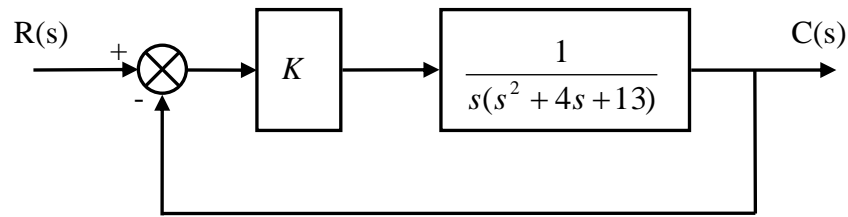| $\omega(rad/s)$	0.5	1.0	1.5	2.0	2.5	3.0	3.5	5.0
$\lvert G(j\omega)\rvert(dB)$								
$\angle G(j\omega)(\deg)$								

(5 marks)

(c) From the Nichol's plot in **Question 5(b),** determine the following for $K = 3.2$:

i. The bandwidth (BW) of the closed-loop system.

ii. The resonant peak value (M_r).

iii. The resonance frequency (ω_r).

(3 marks)

Question 6

Consider a unity feedback system shown in **Figure 9.**

Figure 9: A unity feedback system

(a)   Sketch the Root Locus of the system as K varies from zero to infinities. Show all important calculations, i.e. asymptotes, break points on the real axis, imaginary axis crossing points and angle of departure or arrival, where appropriate.

(15 marks)

(b)   Determine the closed-loop dominant poles of a system at a damping ratio, ζ of 0.4. Indicate the closed-loop poles on the plot and calculate the value of K at this point.

(5 marks)

END OF QUESTION

Appendix 1

1. $G(s) = \dfrac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$

7. $e(\infty) = e_{step}(\infty) = \dfrac{1}{1 + \lim\limits_{s\to 0} G(s)}$

2. $\%OS = e^{-\left(\zeta\pi/\sqrt{1-\zeta^2}\right)} \times 100$

8. $e(\infty) = e_{ramp}(\infty) = \dfrac{1}{\lim\limits_{s\to 0} sG(s)}$

3. $\zeta = \dfrac{-\ln(\%OS/100)}{\sqrt{\pi^2 + \ln^2(\%OS/100)}}$

9. $e(\infty) = e_{parabola}(\infty) = \dfrac{1}{\lim\limits_{s\to 0} s^2 G(s)}$

4. $T_p = \dfrac{\pi}{\omega_n \sqrt{1-\zeta^2}}$

10. $K_p = \lim\limits_{s\to 0} G(s)$

5. $T_s = \dfrac{4}{\zeta\omega_n}$ for 2% criteria

11. $K_v = \lim\limits_{s\to 0} sG(s)$

6. $T_r = \dfrac{\pi/2 + \phi}{\omega_n \sqrt{1-\zeta^2}}$

12. $K_a = \lim\limits_{s\to 0} s^2 G(s)$

where, $\phi = \tan^{-1}\dfrac{\zeta}{\sqrt{1-\zeta^2}}$

Laplace Transform Table

Item no.	$f(t)$	$F(s)$
1.	$\delta(t)$	1
2.	$u(t)$	$\dfrac{1}{s}$
3.	$tu(t)$	$\dfrac{1}{s^2}$
4.	$t^n u(t)$	$\dfrac{n!}{s^{n+1}}$
5.	$e^{-at} u(t)$	$\dfrac{1}{s+a}$
6.	$\sin \omega t u(t)$	$\dfrac{\omega}{s^2 + \omega^2}$
7.	$\cos \omega t u(t)$	$\dfrac{s}{s^2 + \omega^2}$