CONFIDENTIAL

SET A

UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION
SEPTEMBER 2013 SESSION

SUBJECT CODE	:	**FAD 30203**
SUBJECT TITLE	:	**CONTROL ENGINEERING**
LEVEL	:	**DIPLOMA**
TIME / DURATION	:	**(3 HOURS)**
DATE	:	

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 TWO (2) sections. Section A and B. Answer all questions in Section A. For Section B, answer TWO (2) questions only.**
6. **Answer all questions in English.**
7. **Semi-log paper and formula is appended**

THERE ARE 7 PAGES OF QUESTIONS AND 3 PAGES OF APPENDICES, EXCLUDING THIS PAGE.

SECTION A (Total: 60 marks)

INSTRUCTION: Answer all the questions.
Please use the answer booklet provided.

Question 1

(a) Find the inverse Laplace for :

i. $\dfrac{32}{s(s^2+12s+32)}$

ii. $\dfrac{7}{(s+11)(s+12)}$

(10 marks)

(b) Describe how does an open loop system differs from closed-loop systems. List **one (1)** advantage of each system.

(4 marks)

(c) **Figure 1** is the process of controlling liquid level in a tank. The actual level *Ca* is continuously measured using Level Sensor and feedback to be compared with desired input level *Cd.* The excessive liquid will be exhausted through Fluid Outlet Q controlled by Level Controller. Answer the following questions :

i. Determine whether the system is open loop or closed-loop control system. Provide your justification.

(3 marks)

ii. Draw the functional block diagram of the system.

(3 marks)

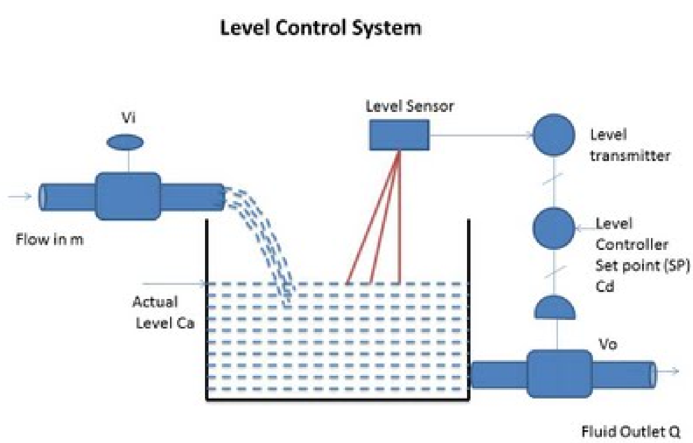


Figure 1: Liquid Level Control System

Question 2

(a) Prove that for a negative-feedback closed-loop control system, the system transfer function is $TF = \frac{G}{1+GH}$, where ***G*** is forward gain and ***H*** is feedback gain.

(5 marks)

(b) Simplify the block diagram of a system shown in **Figure 2** to a single block representing the transfer function, $TF(s) = C(s)/R(s)$.

(13 marks)

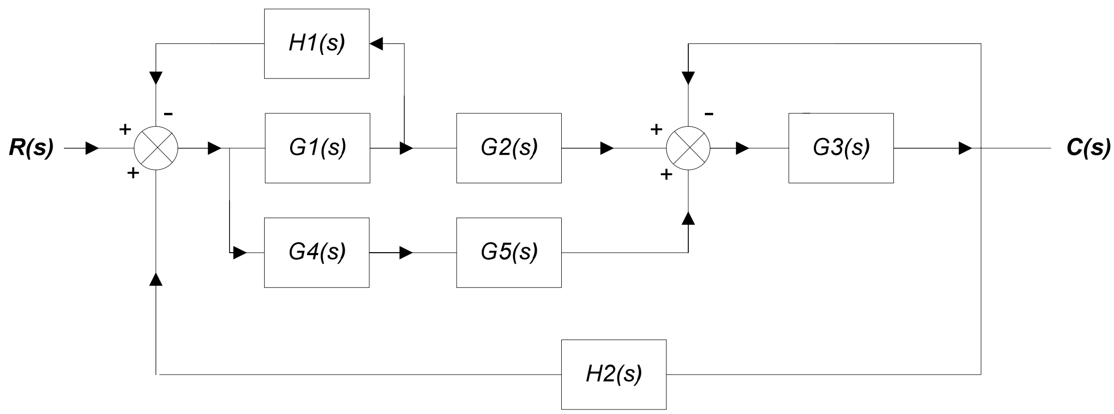


Figure 2: Block Diagram

(c) By referring to **Figure 2**, obtain the transfer function, *TF(s)* if G1(s)=1, G2(s)=2, G3(s)=4, G4(s)=2, G5(s) = 3, H1(s)=1, and H2(s) =1.

(2 marks)

Question 3

(a) A basic mechanical system consist of three passive and linear components; mass, spring and viscous damper. Derive the **mathematical model** that describe the relationship between force *f(t)* and displacement *x(t)* for each components.

(6 marks)

(b) Provide an example of mechanical system that you know.

(2 marks)

(c) Given *R1 = 1 Ω*, *R2 = 2 Ω* and *L = 1 H.* Find the transfer function $\frac{I_2(s)}{V_i(s)}$, of two-loop electrical network shown in **Figure 3**.

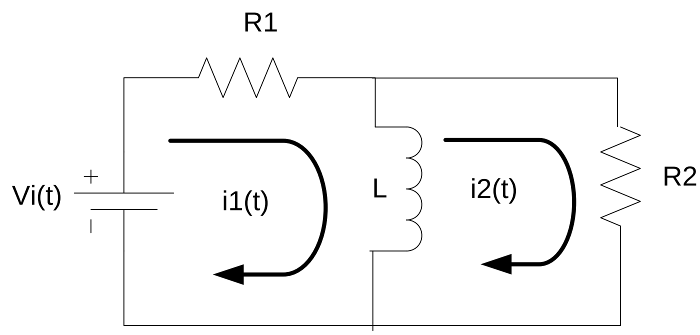


Figure 3: Two-loop electrical network

(12 marks)

SECTION B (Total: 40 marks)

INSTRUCTION: Answer TWO (2) questions only.
Please use the answer booklet provided.

Question 4

(a) Consider the under damped response of second-order system shown in **Figure 4.** Determine the following :

i. Delay time (T_d) (2 marks)

ii. Rise time (T_r) (2 marks)

iii. Settling time (T_s) of 2% criteria (2 marks)

iv. Maximum overshoot (2 marks)

v. Steady state error (2 marks)

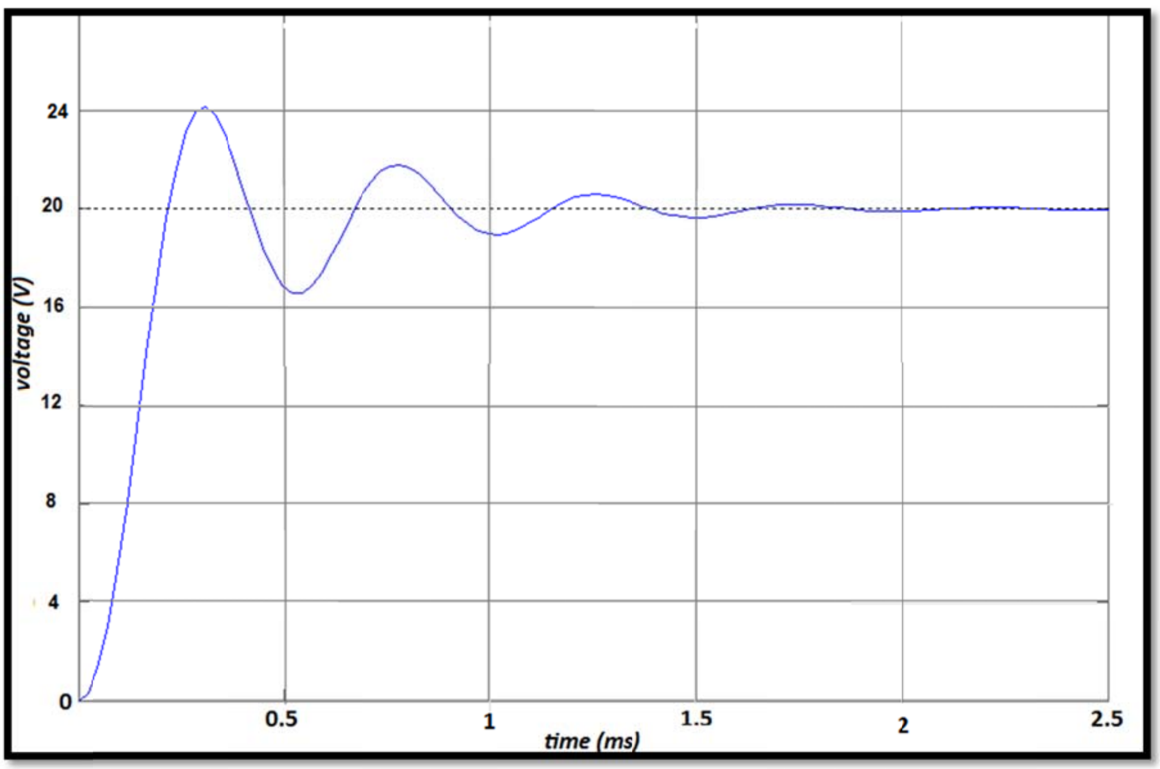


Figure 4: The Under Damped Response of Second-order System

(b) **Figure 5** shows an output response of a first order system to the unit step input function. Answer the following questions.

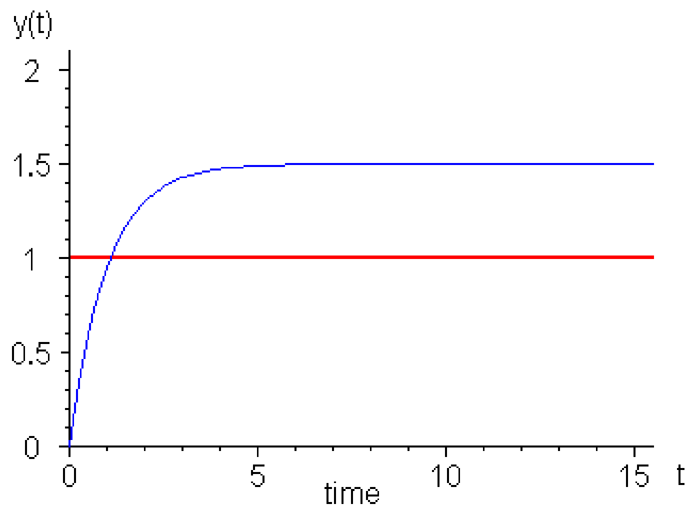


Figure 5: An Output Response of A First-order System

i. Express the above **input function** mathematically.

(2 marks)

ii. Name **four (4)** standard input functions other than shown above.

(2 marks)

iii. General transfer function for first order system is described as $\frac{K}{s+a}$.

Based on above response, find $\boldsymbol{a}$ and $\boldsymbol{K}$.

(6 marks)

Question 5

(a) A proportional controller has a gain of 9. Determine the controller output if the input to the controller is 5 units.

(2 marks)

(b) A derivative controller has a gain of 12. Determine the controller output if the controller is subjected to a constant error of 7.

(2 marks)

(c) Derive the transfer function of PD controller and identify the characteristics of this controller.

(6 marks)

(d) A position control system for a robotic arm is designed to accept a voltage (volts dc) signal from an external source and move the arm correspondingly. Displacement is measured in meters. The transfer function for output displacement ***x(t)*** and input voltage ***e(t)*** is given as $\frac{25}{s+3}$.

Determine the overall transfer function of that system when compensated with a PID controller as shown in **Figure 6**.

(10 marks)

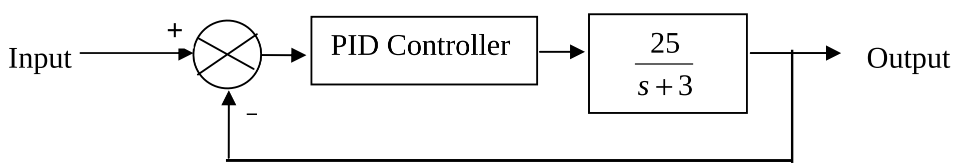


Figure 6: PID controller with plant module system

Question 6

(a) Draw a Bode plot of the unity feedback system shown in **Figure 7**.

(14 marks)

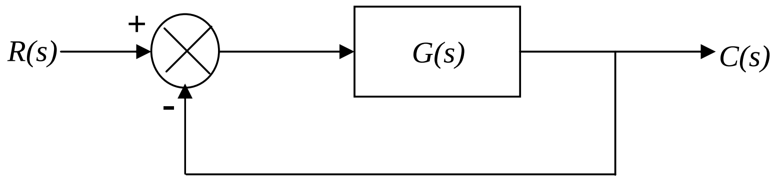


Figure 7: The unity feedback system

Where $G(s) = \dfrac{60}{s(s+5)(s+12)}$

(b) From the Bode plot, determine the following:

i. Gain margin, GM (1 mark)

ii. Phase margin, PM (1 mark)

iii. Gain cross over frequency, ω_{gco} (1 mark)

iv. Phase cross over frequency, ω_{pco} (1 mark)

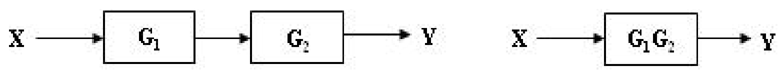
(c) Give your comment on the stability.

(2 marks)

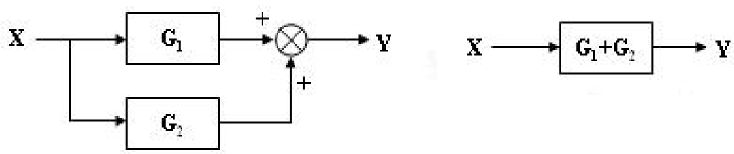
END OF QUESTION

APPENDIX 1: BLOCK DIAGRAMS

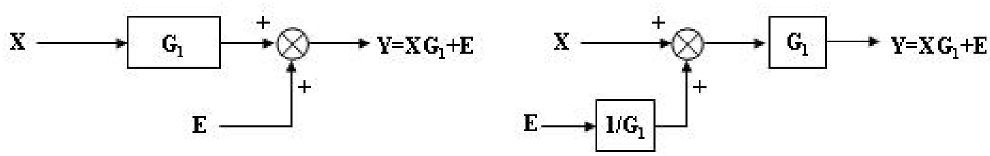
1. Cascading Blocks:



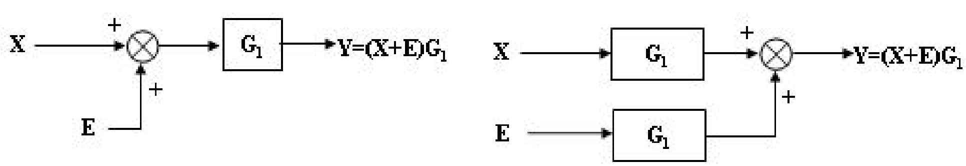
2. Blocks in parallel: Forward Loop



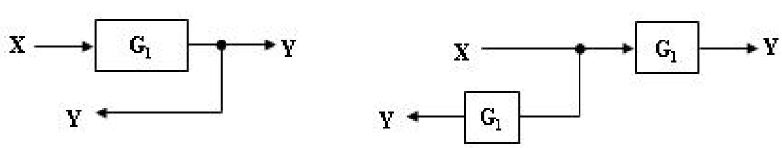
3. Moving the summing ahead of the block:



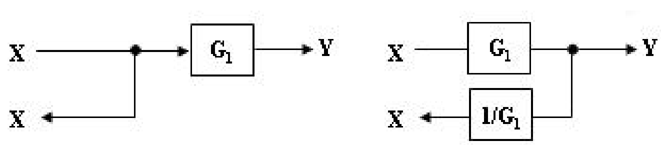
4. Moving the summing beyond the block:



5. Moving the takeoff point ahead of a block:



6. Moving the takeoff point beyond a block:



APPENDIX 2: TABLE OF LAPLACE TRANSFORMS

	Time domain f(t)	Laplace domain F(s)
1	Unit impulse $\delta(t)$	1
2	Unit Step Function $u(t)$	$\frac{1}{s}$
3	Constant K	$\frac{K}{s}$
4	t	$\frac{1}{s^2}$
5	t^2	$\frac{2!}{s^3}$
6	$\frac{t^2}{2!}$	$\frac{1}{s^3}$
7	t^n	$\frac{n!}{s^{n+1}}$
8	$\frac{t^{n-1}}{n!}$	$\frac{1}{s^n}$
9	e^{-at}	$\frac{1}{s+a}$
10	$t \cdot e^{-at}$	$\frac{1}{(s+a)^2}$
11	$\frac{t^2 e^{-at}}{2!}$	$\frac{1}{(s+a)^3}$
12	$\frac{t^{n-1}e^{-at}}{n-1!}$	$\frac{1}{(s+a)^n}$
13	$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
14	$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
15	$\frac{1}{a}\left(1-e^{-at}\right)$	$\frac{1}{s(s+a)}$
16	$\frac{1}{a^2}\left(at-1+e^{-at}\right)$	$\frac{1}{s^2(s+a)}$
17	$\frac{1}{b-a}\left(e^{-at}-e^{-bt}\right)$	$\frac{1}{(s+b)(s+a)}$
18	$e^{-at}\sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
19	$e^{-at}\cos \omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$

APPENDIX 3: FORMULAS

1	$T_s \approx 4T = \frac{4}{\xi\omega_n}$, if 2% of final value $T_s \approx 3T = \frac{3}{\xi\omega_n}$, if 5% of final value
2	$\%OS = \frac{c_{\max} - c_{final}}{c_{final}}$ x 100
3	$\xi = \frac{-\ln(\%OS/100)}{\sqrt{\pi^2 + \ln^2(\%OS/100)}}$