UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2012/2013 Academic Session

June 2013

EBB 338/3 – Process Control
[Kawalan Proses]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains THIRTEEN printed pages and THREE pages APPENDIX before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi TIGA BELAS muka surat beserta TIGA muka surat LAMPIRAN yang bercetak sebelum anda memulakan peperiksaan ini.]

This paper consists of SEVEN questions. ONE question in PART A, TWO questions in PART B, TWO questions in PART C and TWO questions in PART D.
[Kertas soalan ini mengandungi TUJUH soalan. SATU soalan di BAHAGIAN A, DUA soalan di BAHAGIAN B, DUA soalan di BAHAGIAN C dan DUA soalan di BAHAGIAN D.]

Instruction: Answer **FIVE** questions. Answer **ONE** question from PART A, **ONE** question from PART B, **ONE** question from PART C, **ONE** question from PART D and **ONE** question from any parts. If candidate answers more than five questions only the first five questions answered in the answer script would be examined.
*[**Arahan**: Jawab **LIMA** soalan. Jawab **SATU** soalan dari BAHAGIAN A, **SATU** soalan dari BAHAGIAN B, **SATU** soalan dari BAHAGIAN C, **SATU** soalan dari BAHAGIAN D dan **SATU** soalan dari mana-mana bahagian. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]*

The answers to all questions must start on a new page.
[Mulakan jawapan anda untuk semua soalan pada muka surat yang baru.]

You may answer a question either in Bahasa Malaysia or in English.
[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

In the event of any discrepancies, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

...2/-

PART A / *BAHAGIAN A*

1. [a] Define the empirical and mechanistic models.

Terangkan apa yang dimaksudkan dengan model empirik dan model mekanistik.

(10 marks/*markah*)

[b] Explain in what condition we should choose a mechanistic model instead of empirical model.

Jelaskan dalam keadaan bagaimana kita sepatutnya memilih model mekanistik bukannya model empirik.

(20 marks/*markah*)

[c] Automatic control has been applied for a long time since the steam engine time. However, digital computers were not available for these purposes until after the World War II. Explain, how automatic control was implemented physically before digital computation?

Kawalan automatik telah digunakan untuk masa yang lama sejak masa enjin wap. Walau bagaimanapun, komputer digital belum wujud untuk tujuan itu sehingga selepas Perang Dunia II. Jelaskan, bagaimana kawalan automatik secara fizikal dilakukan sebelum pengiraan digital wujud?

(20 marks/*markah*)

[d] The block diagram provides the method for combining individual transfer function into an overall transfer function. Sketch the symbols/components in block diagram which represent:

(i) Signal

(ii) Summing junction

(iii) Pickoff point

(iv) System

Gambarajah blok memberikan cara untuk menggabungkan fungsi pindah individu menjadi satu fungsi pindah keseluruhan. Lakarkan simbol/komponen dalam gambarajah blok yang mewakili:

(i) Isyarat

(ii) Simpang penambahan

(iii) Titik bertolak

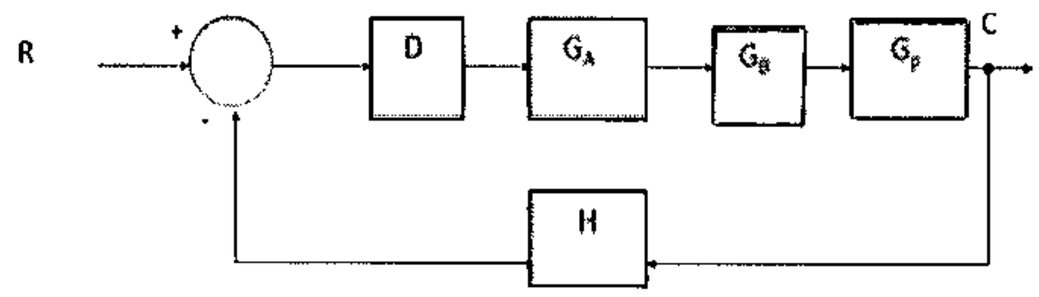
(iv) Sistem

(20 marks/*markah*)

[e] Determine the transfer function for the following systems (i - iii):

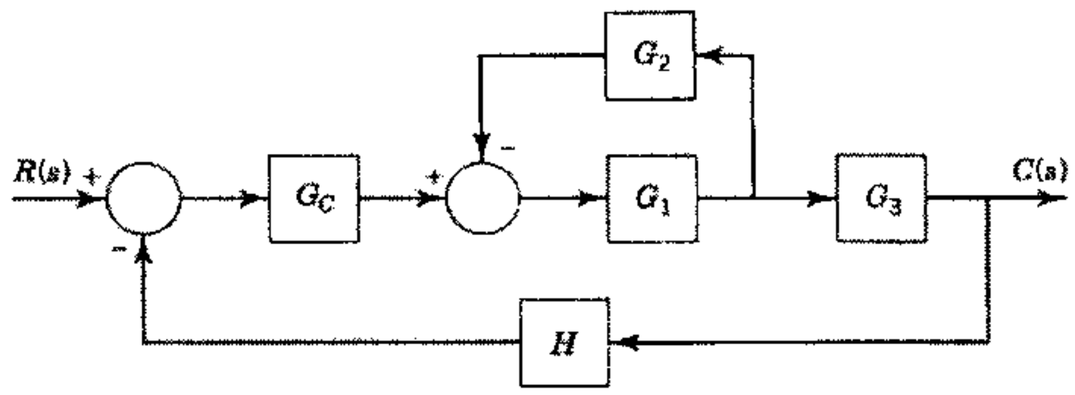
Tentukan fungsi pindah untuk sistem berikut (i - iii):

(i)



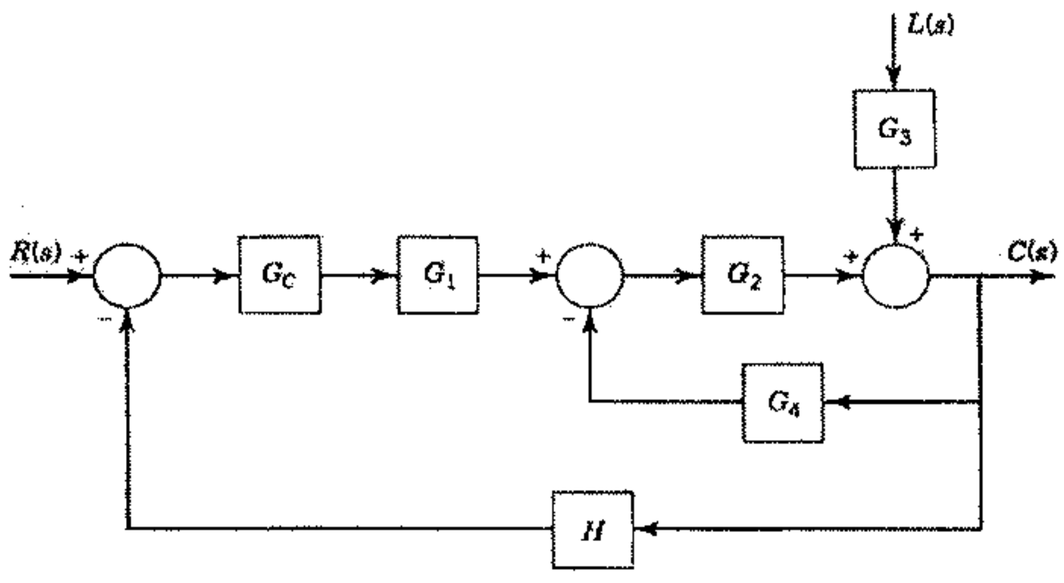
(10 marks/*markah*)

(ii)



(10 marks/*markah*)

(iii)



(10 marks/*markah*)

PART B / *BAHAGIAN B*

2. [a] Figure 1 shows a series arrangement of plant units (distillation columns, reactors, etc.). Explain how this arrangement will provide smooth flow rates that contribute to good operation.

Rajah 1 menunjukkan susunan siri unit loji (kolum penyulingan, reaktor dan lain-lain). Terangkan bagaimana susunan ini akan memberikan kadar aliran lancar yang menyumbang kepada operasi yang baik.

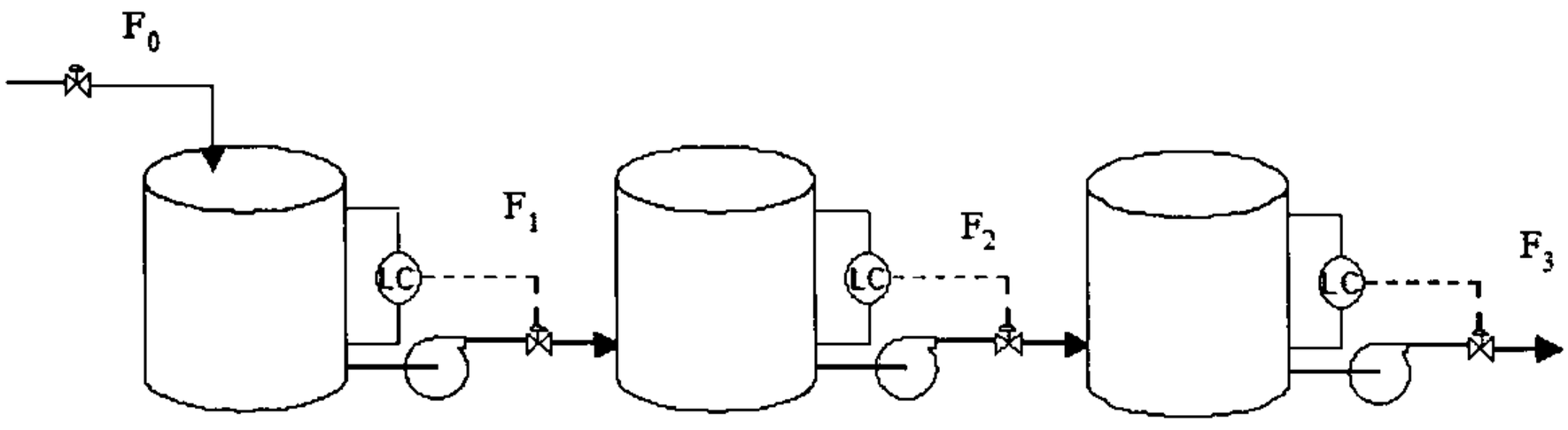


Figure 1 - Series arrangement of plant units

Rajah 1 - Susunan siri unit loji

(30 marks/*markah*)

[b] Solve the following equation using Laplace transform:

Selesaikan persamaan berikut menggunakan jelmaan Laplace:

$$\frac{d^2y}{dt^2} - 10\frac{dy}{dt} + 9y = 5T; \quad y(0) = -1;\ y'(0) = 2$$

(40 marks/*markah*)

[c] Determine the transfer function between output and input for a two-loop electrical system as shown in Figure 2. Given R = 2 Ohm, C = 5 F, L = 4 H, and $V(t)$ = 5 V.

Tentukan fungsi pertukaran di antara keluaran dan masukan bagi suatu gelung kembar sistem elektrik seperti dalam Rajah 2. Diberi R = 2 Ohm, C = 5 F, L = 4 H, dan V(t) = 5 V.

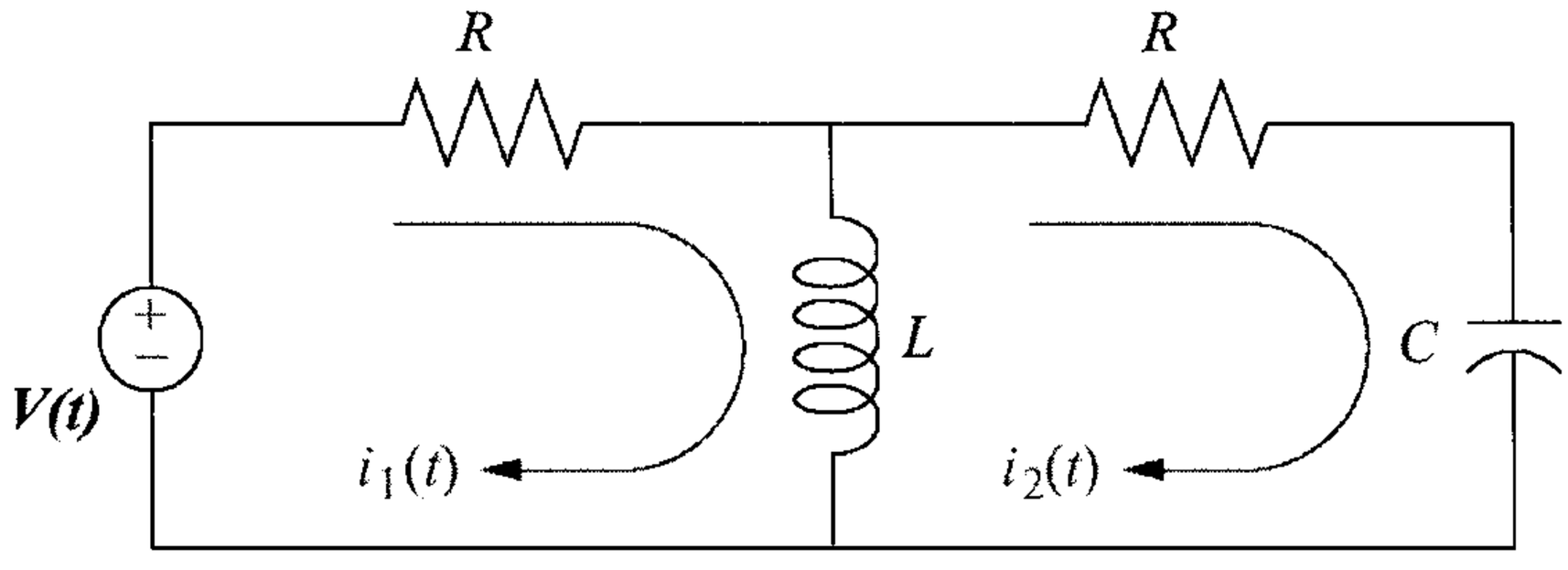


Figure 2 - Two-loop electrical system

Rajah 2 - Gelung kembar sistem elektrik

(30 marks/*markah*)

3. [a] A common method to prepare clay is the so-called three band dryer. Before drying the material is hackled. The hackled material is deformed in order to increase the surface. After that the hackled and deformed material is moved on a steel mesh through the dry room. An air heater is used for drying. The dry material is then cooled. Sketch the phase model of production, consists of all process elements "clay preparation" for this process and identify an important part on the processes that need to be controlled properly.

Kaedah yang lazim untuk penyediaan tanahliat dinamakan pengering tiga jalur. Sebelum dikeringkan bahan dipecah-pecah. Bahan yang dipecah diubahbentuk untuk meningkatkan permukaan. Selepas itu, bahan yang telah dibentuk digerakkan di atas rangkaian keluli melalui bilik kering. Pemanas udara digunakan untuk pengeringan. Bahan yang kering kemudiannya disejukkan. Lukis model fasa produksi yang terdiri daripada semua elemen proses "penyediaan tanahliat" bagi proses ini dan kenalpasti satu bahagian penting dalam proses yang perlu dikawal dengan betul.

(50 marks/*markah*)

[b] A thermistor has a response to temperature represented by:

Sebuah termistor yang bertindakbalas dengan suhu diberikan oleh:

$$R = R_o\, e^{-0.1T}$$

where R_o = 10 kΩ and T in °C. Construct the linear model for thermistor at 20°C and determine the temperature variation range.

di mana R_o = 10 kΩ dan T dalam °C. Bina model linear bagi termistor pada 20°C dan tentukan julat perubahan suhu.

(50 marks/*markah*)

PART C / *BAHAGIAN C*

4. [a] Discuss five (5) aspects to be considered when designing a feedback control system. Give an example for each of the aspect.

Bincangkan lima (5) aspek yang perlu dipertimbangkan semasa merekabentuk suatu sistem kawalan suap balik. Beri satu contoh untuk setiap aspek.

(50 marks/*markah*)

[b] (i) What is the transfer function for below negative feedback block diagram as illustrated in Figure 3?

Apakah fungsi pindah untuk gambarajah blok suap balik negatif yang ditunjukkan di Rajah 3?

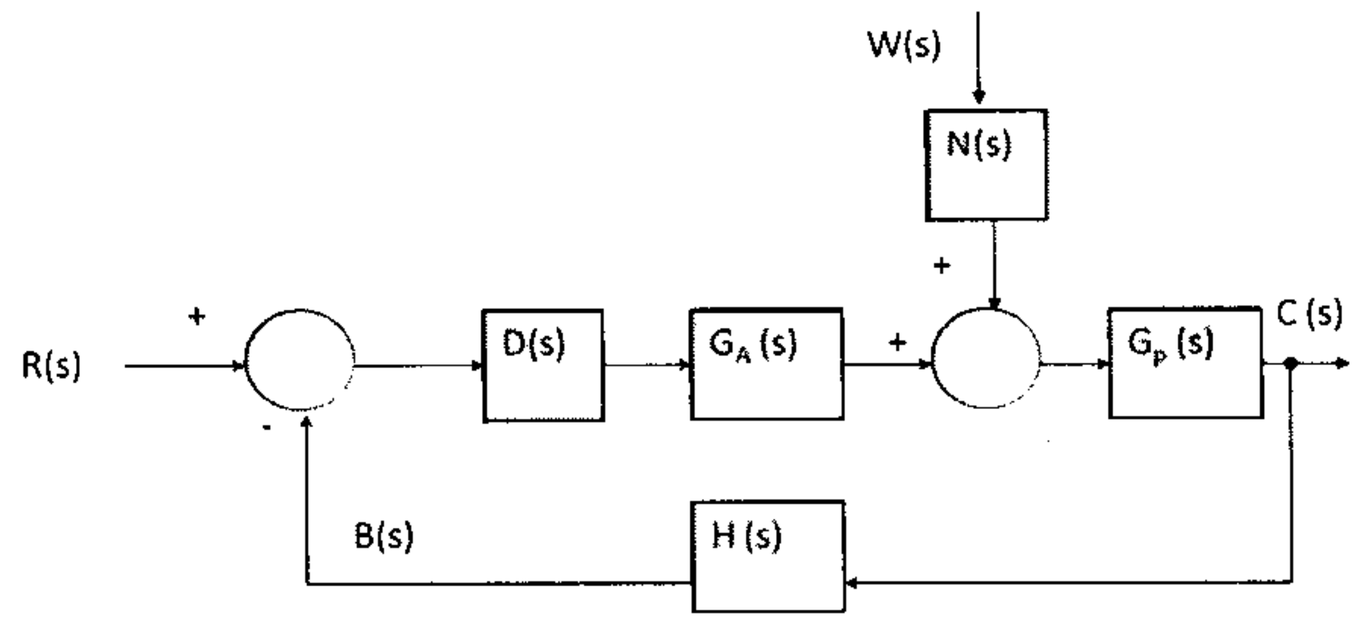


Figure 3 - A typical block diagram of negative feedback control system

Rajah 3 - Gambarajah blok bagi sistem suap balik negatif

(10 marks/*markah*)

(ii) Discuss two (2) advantages and two disadvantages of using high loop gain in this negative feedback system.

Bincangkan dua (2) kelebihan dan kelemahan untuk sistem suap balik negatif ini yang mempunyai gandaan gelung tinggi.

(40 marks/*markah*)

5. [a] List three (3) characteristics of a PD controller.

Senaraikan tiga (3) ciri-ciri sebuah pengawal PD.

(30 marks/*markah*)

[b] A PD controller has a parallel arrangement as shown in Figure 4.

Sebuah PD pengawal telah disusun secara selari seperti ditunjukkan dalam Rajah 4.

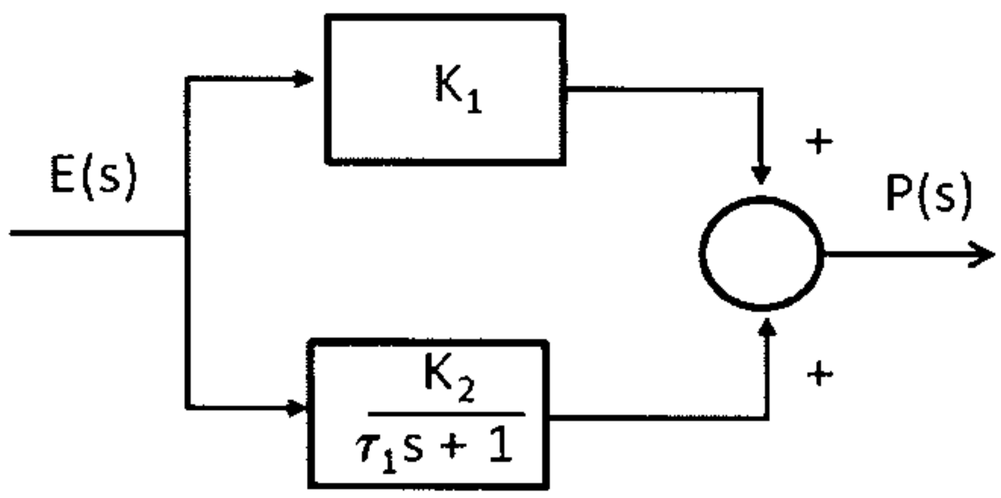


Figure 4 - A parallel PD controller

Rajah 4 - Pengawal PD selari

(i) What is the transfer function of this parallel PD controller?

Apakah fungsi pindah untuk pengawal PD selari ini?

(10 marks/*markah*)

(ii) Parallel PD controller has a general form of transfer function given as:

Pengawal PD selari mempunyai fungsi pindah umum seperti ditunjukkan di bawah:

$$G_a = K_c\left(\frac{\tau_D s + 1}{\alpha\tau_D s + 1}\right)$$

Find the expression for K_1, K_2 and τ_1 in the terms of K_c, τ_D and α.

Carikan K_1, K_2 dan τ_1 dalam sebutan K_c, τ_D dan α.

(25 marks/*markah*)

(iii) Calculate the values of K_1, K_2 and τ_1 if K_c =2, τ_D = 2 and α = 0.2.

Kirakan nilai K_1, K_2 dan τ_1 jika K_c =2, τ_D = 2 dan α = 0.2.

(30 marks/*markah*)

(iv) What is the transfer function of this parallel PD controller with the calculated K_1, K_2 and τ_1 values in 5[b](iii)?

Apakah fungsi pindah pengawal PD ini berdasarkan nilai-nilai K_1, K_2 dan τ_1 yang dikira di bahagian 5[b](iii)?

(5 marks/*markah*)

PART D / *BAHAGIAN D*

6. [a] Define the following terms in process control perspective:

(i) Offset

(ii) Measurement lag

Takrifkan istilah-istilah berikut berasaskan perspektif kawalan proses:

(i) Ofset

(ii) Pengukuran susulan

(20 marks/*markah*)

[b] The set point of the control system shown in Figure 5 is given a step change of 0.1 unit.

Titik set pada sistem kawalan proses yang ditunjukkan di Rajah 5 telah diberikan suatu penukaran langkah sebanyak 0.1 unit.

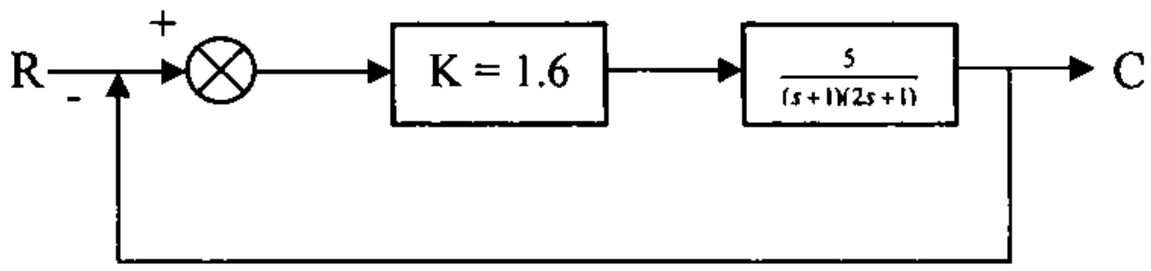


Figure 5 - Block diagram for a process

Rajah 5 - Gambarajah blok bagi satu proses

Determine:

Tentukan:

(i) The maximum value of C and the time at which it occurs.

Nilai maksimum bagi C dan masa di mana ia berlaku.

(45 marks/*markah*)

(ii) The offset

Ofset

(10 marks/*markah*)

(iii) The period of oscillation.

Kala ayunan

(25 marks/*markah*)

7. [a] Explain the purpose of a Routh stability test.

Terangkan tujuan suatu ujian kestabilan Routh.

(20 marks/*markah*)

[b] Write the characteristic equation and construct the Routh array for the control system shown in Figure 6.

Tuliskan persamaan cirian dan bentukkan tatasusunan Routh bagi sistem kawalan yang ditunjukkan di Rajah 6.

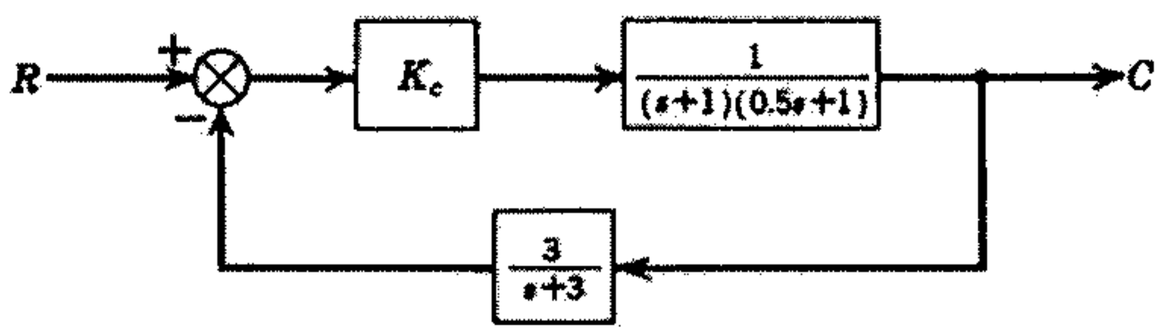


Figure 6 - Block diagram for a process

Rajah 6 - Gambarajah blok bagi satu proses

(40 marks/*markah*)

[c] Is the system in Figure 6 stable for (i) K_c = 9.5, (ii) K_c = 11, (iii) K_c =12. Explain your answer.

Adakah sistem di Rajah 6 stabil untuk (i) K_c = 9.5, (ii) K_c = 11, (iii) K_c =12. Terangkan jawapan anda.

(40 marks/*markah*)

- oooOooo -

APPENDIX 1

LAMPIRAN 1

Table of Laplace Transforms

$f(t)=\mathcal{L}^{-1}\{F(s)\}$	$F(s)=\mathcal{L}\{f(t)\}$	$f(t)=\mathcal{L}^{-1}\{F(s)\}$	$F(s)=\mathcal{L}\{f(t)\}$
1. 1	$\frac{1}{s}$	2. e^{at}	$\frac{1}{s-a}$
3. $t^n,\ n=1,2,3,\ldots$	$\frac{n!}{s^{n+1}}$	4. $t^p,\ p>-1$	$\frac{\Gamma(p+1)}{s^{p+1}}$
5. $\sqrt{t}$	$\frac{\sqrt{\pi}}{2s^{\frac{3}{2}}}$	6. $t^{n-\frac{1}{2}},\ n=1,2,3,\ldots$	$\frac{1\cdot3\cdot5\cdots(2n-1)\sqrt{\pi}}{2^n s^{n+\frac{1}{2}}}$
7. $\sin(at)$	$\frac{a}{s^2+a^2}$	8. $\cos(at)$	$\frac{s}{s^2+a^2}$
9. $t\sin(at)$	$\frac{2as}{(s^2+a^2)^2}$	10. $t\cos(at)$	$\frac{s^2-a^2}{(s^2+a^2)^2}$
11. $\sin(at)-at\cos(at)$	$\frac{2a^3}{(s^2+a^2)^2}$	12. $\sin(at)+at\cos(at)$	$\frac{2as^2}{(s^2+a^2)^2}$
13. $\cos(at)-at\sin(at)$	$\frac{s(s^2-a^2)}{(s^2+a^2)^2}$	14. $\cos(at)+at\sin(at)$	$\frac{s(s^2+3a^2)}{(s^2+a^2)^2}$
15. $\sin(at+b)$	$\frac{s\sin(b)+a\cos(b)}{s^2+a^2}$	16. $\cos(at+b)$	$\frac{s\cos(b)-a\sin(b)}{s^2+a^2}$
17. $\sinh(at)$	$\frac{a}{s^2-a^2}$	18. $\cosh(at)$	$\frac{s}{s^2-a^2}$
19. $e^{at}\sin(bt)$	$\frac{b}{(s-a)^2+b^2}$	20. $e^{at}\cos(bt)$	$\frac{s-a}{(s-a)^2+b^2}$
21. $e^{at}\sinh(bt)$	$\frac{b}{(s-a)^2-b^2}$	22. $e^{at}\cosh(bt)$	$\frac{s-a}{(s-a)^2-b^2}$
23. $t^n e^{at},\ n=1,2,3,\ldots$	$\frac{n!}{(s-a)^{n+1}}$	24. $f(ct)$	$\frac{1}{c}F\left(\frac{s}{c}\right)$
25. $u_c(t)=u(t-c)$ <u>Heaviside Function</u>	$\frac{e^{-cs}}{s}$	26. $\delta(t-c)$ <u>Dirac Delta Function</u>	e^{-cs}
27. $u_c(t)f(t-c)$	$e^{-cs}F(s)$	28. $u_c(t)g(t)$	$e^{-cs}\mathcal{L}\{g(t+c)\}$
29. $e^{ct}f(t)$	$F(s-c)$	30. $t^n f(t),\ n=1,2,3,\ldots$	$(-1)^n F^{(n)}(s)$
31. $\frac{1}{t}f(t)$	$\int_s^\infty F(u)\,du$	32. $\int_0^t f(v)\,dv$	$\frac{F(s)}{s}$
33. $\int_0^t f(t-\tau)g(\tau)\,d\tau$	$F(s)G(s)$	34. $f(t+T)=f(t)$	$\frac{\int_0^T e^{-st}f(t)\,dt}{1-e^{-sT}}$
35. $f'(t)$	$sF(s)-f(0)$	36. $f''(t)$	$s^2F(s)-sf(0)-f'(0)$

37. $f^{(n)}(t)$ $\quad s^nF(s)-s^{n-1}f(0)-s^{n-2}f'(0)\cdots-sf^{(n-2)}(0)-f^{(n-1)}(0)$

APPENDIX 2

LAMPIRAN 2

$f(t)$	$F(s) = \int_0^\infty f(t)e^{-st}\,dt$
$f + g$	$F + G$
$\alpha f \ (\alpha \in \mathbf{R})$	αF
$\frac{df}{dt}$	$sF(s) - f(0)$
$\frac{d^k f}{dt^k}$	$s^k F(s) - s^{k-1} f(0) - s^{k-2}\frac{df}{dt}(0) - \cdots - \frac{d^{k-1} f}{dt^{k-1}}(0)$
$g(t) = \int_0^t f(\tau)\,d\tau$	$G(s) = \frac{F(s)}{s}$
$f(\alpha t), \alpha > 0$	$\frac{1}{\alpha}F(s/\alpha)$
$e^{at} f(t)$	$F(s - a)$
$tf(t)$	$-\frac{dF}{ds}$
$t^k f(t)$	$(-1)^k \frac{d^k F(s)}{ds^k}$
$\frac{f(t)}{t}$	$\int_s^\infty F(s)\,ds$
$g(t) = \begin{cases} 0 & 0 \le t < T \\ f(t-T) & t \ge T \end{cases}, T \ge 0$	$G(s) = e^{-sT}F(s)$

APPENDIX 3

LAMPIRAN 3

1	$\frac{1}{s}$
δ	1
$\delta^{(k)}$	s^k
t	$\frac{1}{s^2}$
$\frac{t^k}{k!}$, $k \geq 0$	$\frac{1}{s^{k+1}}$
e^{at}	$\frac{1}{s-a}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2} = \frac{1/2}{s-j\omega} + \frac{1/2}{s+j\omega}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2} = \frac{1/2j}{s-j\omega} - \frac{1/2j}{s+j\omega}$
$\cos(\omega t + \phi)$	$\frac{s\cos\phi - \omega\sin\phi}{s^2+\omega^2}$
$e^{-at}\cos \omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$e^{-at}\sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$