
UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2014/2015 Academic Session

June 2015

EBB 338/3 – Process Control *[Kawalan Proses]*

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains ELEVEN printed pages and THREE pages APPENDIX before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEBELAS 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, THREE questions in PART B, and THREE questions in PART C.

[Kertas soalan ini mengandungi TUJUH soalan. SATU soalan di BAHAGIAN A, TIGA soalan di BAHAGIAN B dan TIGA soalan di BAHAGIAN C.]

Instruction: Answer FIVE questions. Answer ALL questions from PART A, TWO questions from PART B and TWO questions from PART C. If a candidate answers more than five questions only the first five questions answered in the answer script would be examined.

[Arahan: Jawab LIMA soalan. Jawab SEMUA soalan dari BAHAGIAN A, DUA soalan dari BAHAGIAN B dan DUA soalan dari BAHAGIAN C. 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 in the examination questions, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

PART A / BAHAGIAN A

1. [a] (i) Two types of variations, i.e. common cause variation and special cause variation, could normally show up on a control charts. Sketch and explain these variations in a control chart.

Dua jenis perubahan, iaitu perubahan umum dan perubahan sebab khas, biasanya boleh dijumpai pada carta kawalan. Lakar dan terangkan perubahan-perubahan ini dalam carta kawalan.

(20 marks/markah)

- (ii) What does it mean when a process is said to be in statistical control?

Apakah yang dimaksudkan apabila suatu proses dikatakan dalam kawalan statistik?

(10 marks/markah)

- (iii) A system is represented by the following differential equation. Solve for $y(t)$ using Laplace transform with the initial condition of $y(0) = 2$ and $\dot{y}(0) = -1$.

$$\frac{d^2y}{dt^2} + 3 \frac{dy}{dt} + 3y = 1$$

Suatu sistem boleh diwakili oleh persamaan pembezaan di bawah. Selesaikan $y(t)$ dengan menggunakan transformasi Laplace dengan syarat awal $y(0) = 2$ dan $\dot{y}(0) = -1$.

$$\frac{d^2y}{dt^2} + 3 \frac{dy}{dt} + 3y = 1$$

(20 marks/markah)

- [b] Discuss any two (2) performance criteria's that the closed-loop system should satisfy. Your answer should include a suitable sketch or diagram.

Bincangkan sebarang dua (2) kriteria prestasi yang memenuhi keperluan sesuatu sistem gelung tertutup. Lakaran atau rajah sesuai perlu diletakkan bersama jawapan anda.

(50 marks/markah)

... 3/-

PART B / BAHAGIAN B

2. A tube furnace is equipped with a feedback control system in order to achieve desired operating temperature as shown in Figure 1.

Sebuah relau tiub mempunyai sistem kawalan suap-balik untuk mencapai suhu operasi yang diinginkan seperti ditunjukkan dalam Rajah 1.

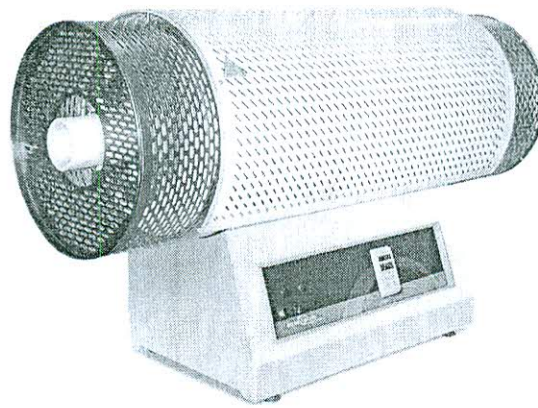


Figure 1 - A horizontal tube furnace

Rajah 1 - Relau tiub mendatar

- [a] Sketch an operational block diagram for the tube furnace. Label the element blocks and signals in your block diagram.

Lakarkan gambarajah blok operasi bagi relau tiub ini. Labelkan blok elemen dan isyarat-isyarat dalam gambarajah blok anda.

(40 marks/markah)

- [b] Explain the operation of a feedback control system which helps the furnace to maintain its temperature at 800°C.

Terangkan operasi sistem kawalan suap-balik yang membantu relau tersebut mengekalkan suhu pada 800°C.

(30 marks/markah)

- [c] Discuss two control objectives that could be achieved by the control system of tube furnace.

Bincangkan dua objektif kawalan yang boleh dicapai bagi sistem kawalan relau tiub.

(30 marks/markah)

3. [a] The block diagram of a control system is illustrated in Figure 2. Determine the equivalent transfer function, $T(s) = Y(s)/R(s)$ using
- Block diagram reduction rules, and
 - Mason's gain rule.

Gambarajah blok bagi sebuah sistem kawalan ditunjukkan pada Rajah 2. Tentukan fungsi pindah yang seiring, $T(s) = Y(s)/R(s)$ dengan menggunakan

- Peraturan penurunan gambarajah blok, dan*
- Peraturan gandaan Mason.*

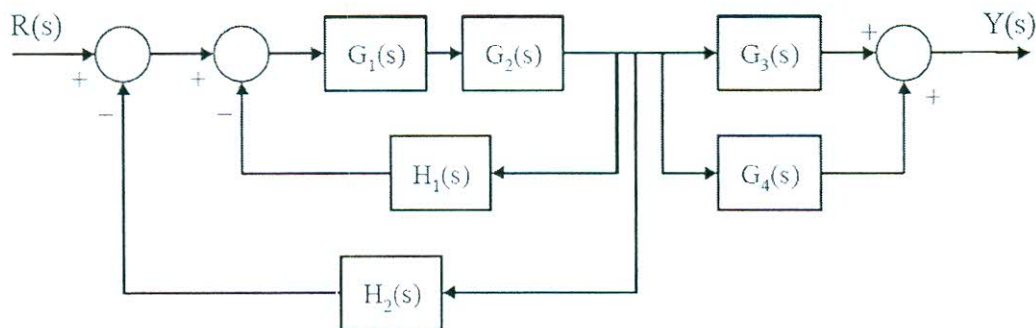


Figure 2 - Block diagram of a control system

Rajah 2 - Gambarajah blok bagi sebuah sistem kawalan

(60 marks/markah)

- [b] A waste stream (dilute nitric acid) is neutralized by adding a base stream (sodium hydroxide) of known concentration to a stirred neutralization tank as shown in Figure 3. The concentration and the flow rate of the waste acid stream vary unpredictably. The flow rates of the waste stream and base stream can be measured. The effluent stream pH can be measured but a significant time delay occurs due to the downstream location of pH probe. If the waste treatment system is represented by

$$Y(s) = \frac{2 + e^{-3s}}{(s + 3)(s + 2)}$$

Find the inverse Laplace transform of this system. The delayed signal can be represented as $y(t - \theta)$ where θ is the time delay and $L[y(t - \theta)] = e^{-\theta s} Y(s)$.

Suatu aliran buangan (asid nitrik cair) akan dineutralkan dengan penambahan suatu aliran bes (natrium hidroksida) dengan kepekatan yang diketahui dalam sebuah tangki peneutralan teraduk seperti ditunjukkan dalam Rajah 3. Kepekatan dan kadar aliran buangan tersebut berubah tanpa jangkaan. Kadar aliran buangan dan bes boleh diukur. Malahan, pH aliran tersebut boleh diukur tetapi dengan masa lenguh yang panjang disebabkan kedudukan alat pH yang terletak di hilir. Jika sistem rawatan buangan boleh diwakili dengan

$$Y(s) = \frac{2 + e^{-3s}}{(s + 3)(s + 2)}$$

Carikan songsangan transformasi Laplace bagi sistem tersebut. Isyarat lenguh boleh diwakili dengan $y(t - \theta)$ di mana θ adalah masa lenguh dan $L[y(t - \theta)] = e^{-\theta s} Y(s)$.

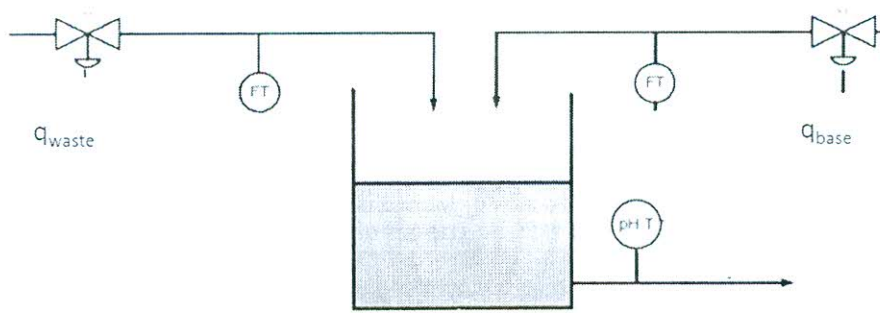


Figure 3 - Waste water treatment tank

Rajah 3 - Tangki rawatan buangan air

(40 marks/markah)

4. [a] (i) Define the transfer function.

Takrifkan fungsi pindah.

(5 marks/markah)

- (ii) Why do transfer function for mechanical networks look identical to transfer function for electrical networks? Give three examples.

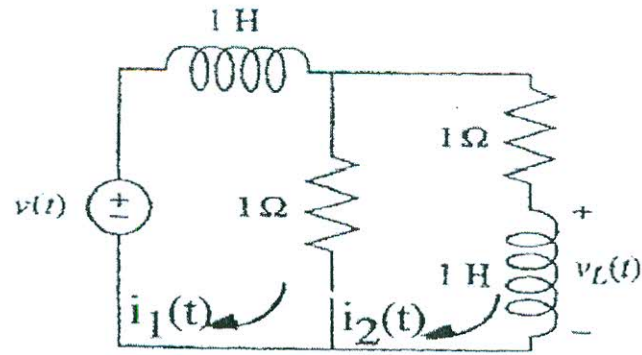
Kenapa fungsi pindah litar mekanikal seiras dengan fungsi pindah litar elektrik? Berikan tiga contoh.

(20 marks/markah)

- (iii) Determine the transfer function, $G(s) = V_L(s)/V(s)$ for each networks as shown in Figure 4.

Tentukan fungsi pindah $G(s) = V_L(s)/V(s)$ bagi setiap litar yang ditunjukkan dalam Rajah 4.

(a)



(b)

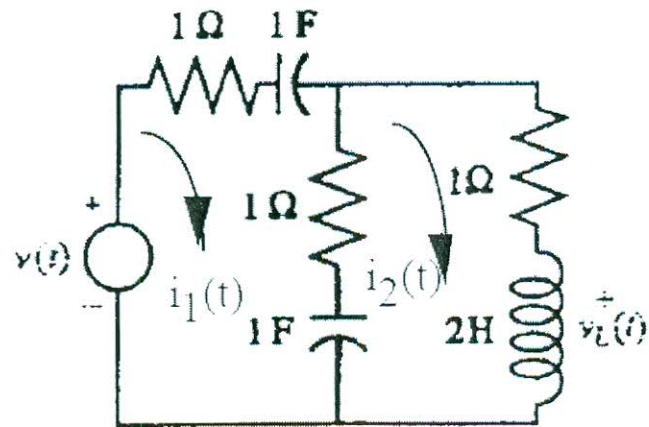


Figure 4 - Electrical network of devices

Rajah 4 - Peranti litar elektrik

(30 marks/markah)

- [b] Figure 5 illustrates a chemical mixing tank. By assuming that the density of the input and output streams are very similar and the flow rates of f_1 and f_2 are constant. Construct a mathematical model, its transfer function and block diagram for this mixing process in order to understand how each inlet concentration affects the outlet concentration.

Rajah 5 menunjukkan sebuah tangki pencampuran kimia. Dengan menganggapkan ketumpatan aliran input dan output adalah serupa dan kadar aliran f_1 dan f_2 adalah pemalar. Rumuskan satu model matematik, fungsi pindah dan gambarajah blok untuk proses pencampuran ini supaya dapat mengetahui bagaimana kepekatan salur masuk mempengaruhi kepekatan salur keluar.

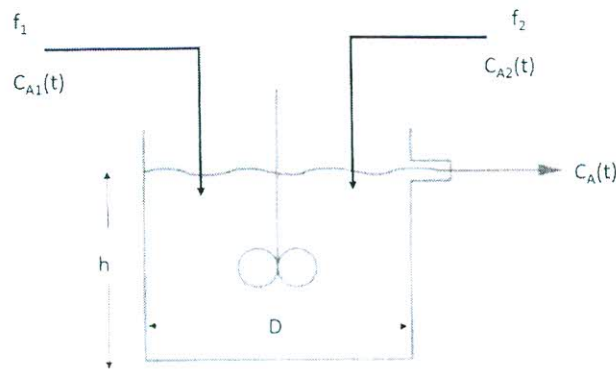


Figure 5 - Chemical mixing tank

Rajah 5 - Tangki pencampuran kimia

(45 marks/markah)

PART C / BAHAGIAN C

5. [a] State the characteristics of proportional (P), integral (I) and derivative (D) control modes in control system.

Nyatakan ciri-ciri mod kawalan berkadaran (P), kamiran (I) dan hasil bezaan (D) di dalam sistem kawalan.

(30 marks/markah)

- [b] Explain the need to combine all the three control modes (P, I, D) in a same control system.

Terangkan keperluan kombinasi kesemua mod kawalan (P, I, D) di dalam sistem kawalan yang sama perlu dilakukan.

(40 marks/markah)

- [c] A pneumatic proportional controller is used to control the cold stream outlet temperature within the range of 120 to 180°C. The controller gain (K_c) is adjusted so that the output pressure goes from 5 Pa (valve fully closed) to 13 Pa (valve fully open) as the temperature goes from 130 to 134°C with the set point held constant. Determine the controller gain (K_c) and the error in temperature that will cause the control valve to go from fully closed to fully open.

Pengawal berkadaran pneumatik digunakan bagi mengawal suhu alur keluar arus sejuk pada julat 120 sehingga 180°C. Gandaan kawalan (K_c) diubah supaya tekanan keluaran berubah dari 5 Pa (injal tertutup sepenuhnya) kepada 13 Pa (injal terbuka sepenuhnya) apabila suhu meningkat dari 130 - 134°C dengan titik set dibiarkan tetap. Tentukan gandaan kawalan (K_c) dan ralat suhu yang menyebabkan injap kawalan berubah dari tertutup sepenuhnya kepada terbuka sepenuhnya.

(30 marks/markah)

6. [a] For a given transfer function, sketch the curves for control variables (CV) vs. time (t). Use $R(s) = \frac{5}{s}$. Assume system in stable condition.

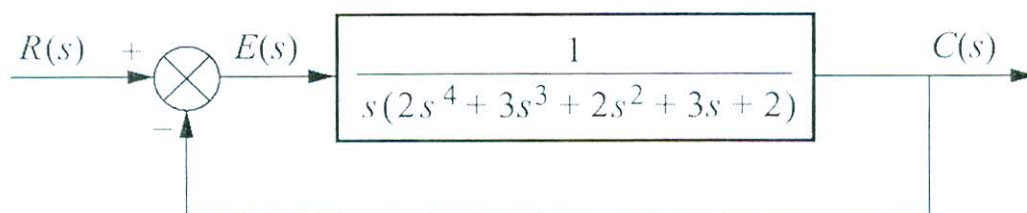
Bagi fungsi pemindahan berikut, lakarkan keluk pembolehubah kawalan (CV) melawan masa (t). Gunakan $R(S) = \frac{5}{S}$. Anggap sistem dalam keadaan stabil.

$$G(s) = \frac{Y(s)}{R(s)} = \frac{1}{s^2 + 3s + 2}$$

(30 marks/markah)

- [b] Determine the stability of the following system using Routh-Hurwitz criterion.

Tentukan kestabilan bagi sistem berikut menggunakan kriteria Routh-Hurwitz.



(30 marks/markah)

- [c] Calculate parameter K in order to ensure that the system is stable if the characteristic equation for given system is:

$$S^4 + 3S^3 + 3S^2 + 2S + (K + 1) = 0$$

Kirakan parameter K bagi memastikan sistem adalah stabil jika persamaan pencirian bagi sistem diberi adalah:

$$S^4 + 3S^3 + 3S^2 + 2S + (K + 1) = 0$$

(40 marks/markah)

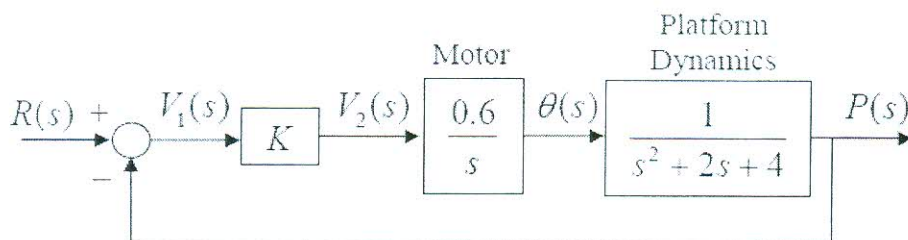
7. [a] Discuss the advantages of Root Locus approach for determining the stability of feedback control system.

Bincangkan kelebihan pendekatan kaedah Londa Punca bagi menentukan kestabilan sistem kestabilan suap balik.

(30 marks/markah)

- [b] Analyze the Root Locus diagram for the following closed loop system.

Buat analisa terhadap gambarajah Londa Punca bagi sistem gelung tertutup berikut.



(70 marks/markah)

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. $t^n, n=1, 2, 3, \dots$	$\frac{n!}{s^{n+1}}$	4. $t^p, p > -1$	$\frac{\Gamma(p+1)}{s^{p+1}}$
5. \sqrt{t}	$\frac{\sqrt{\pi}}{2s^{3/2}}$	6. $t^{n-1/2}, n=1, 2, 3, \dots$	$\frac{1 \cdot 3 \cdot 5 \cdots (2n-1)\sqrt{\pi}}{2^n s^{n+1/2}}$
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. $t^n e^{at}, n=1, 2, 3, \dots$	$\frac{n!}{(s-a)^{n+1}}$	24. $f(ct)$	$\frac{1}{c} F\left(\frac{s}{c}\right)$
25. $u_c(t) = u(t-c)$ Heaviside Function	$\frac{e^{-cs}}{s}$	26. $\delta(t-c)$ Dirac Delta Function	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. $t^n f(t), n=1, 2, 3, \dots$	$(-1)^n F^{(n)}(s)$
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. $f''(t)$	$s^2 F(s) - sf'(0) - f''(0)$
37. $f^{(n)}(t)$	$s^n F(s) - s^{n-1} f(0) - s^{n-2} f'(0) - \dots - sf^{(n-2)}(0) - f^{(n-1)}(0)$		

APPENDIX 2**LAMPIRAN 2**

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

APPENDIX 3LAMPIRAN 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}	$\frac{1}{s-a}$
$\cos \omega t$	$\frac{s}{s^2 + \omega^2} = \frac{1/2}{s-j\omega} + \frac{1/2}{s+j\omega}$
$\sin \omega t$	$\frac{\omega}{s^2 + \omega^2} = \frac{1/2j}{s-j\omega} - \frac{1/2j}{s+j\omega}$
$\cos(\omega t + \phi)$	$\frac{s \cos \phi - \omega \sin \phi}{s^2 + \omega^2}$
$e^{-at} \cos \omega t$	$\frac{s+a}{(s+a)^2 + \omega^2}$
$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2 + \omega^2}$
