First Semester Examination
2024/2025 Academic Session

July/August 2025

EBB438/3 – Process Control
[Kawalan Proses]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains TWELVE (12) pages of printed material including TWO (2) APPENDIX before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi DUA BELAS (12) muka surat yang bercetak termasuk DUA (2) LAMPIRAN sebelum anda memulakan peperiksaan ini.]

Instruction: Answer **FIVE(5)** questions. PART A is **COMPULSORY**. Answer **TWO(2)** questions from PART B and **TWO(2)** questions from PART C. All questions carry the same marks.

*[**Arahan**: Jawab **LIMA(5)** soalan. BAHAGIAN A **WAJIB** dijawab. Jawab **DUA(2)** soalan dari BAHAGIAN B dan **DUA(2)** soalan dari BAHAGIAN C. Semua soalan membawa jumlah markah yang sama.]*

In the event of any discrepancies, the English version shall be used.

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

Should any candidate be caught cheating or in possession of materials not authorised to be brought into the Examination Hall during the examination, appropriate disciplinary action will be taken against the candidate concerned. In the event a candidate is found guilty of cheating, he/she can be expelled from the University.

[Sekiranya seseorang calon didapati meniru/menipu ataupun mempunyai bahan-bahan yang tidak dibenarkan dibawa ke dalam Dewan Peperiksaan semasa peperiksaan diadakan, tindakan displin yang sewajarnya akan dikenakan terhadap calon berkenaan. Jika seseorang calon didapati bersalah meniru/menipu beliau boleh disingkir dari Universiti.]

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PART A / *BAHAGIAN A*

(1). (a). (i). What is the definition of “Process”?
Apakah definisi bagi "Proses"?

(1 mark/*markah*)

(ii). Figure 1 illustrates the float glass forming process. Conduct a process mapping for this operation by identifying two manipulated inputs, two disturbance inputs, and two output variables.

Rajah 1 menggambarkan proses pembentukan kaca apungan. Bina pemetaan proses untuk operasi ini dengan mengenal pasti dua input yang boleh dimanipulasi, dua input gangguan dan dua pembolehubah output.

(7 marks/*markah*)

(iii). How can process mapping help in process control?
Bagaimanakah pemetaan proses boleh membantu dalam kawalan proses?

(2 marks/*markah*)

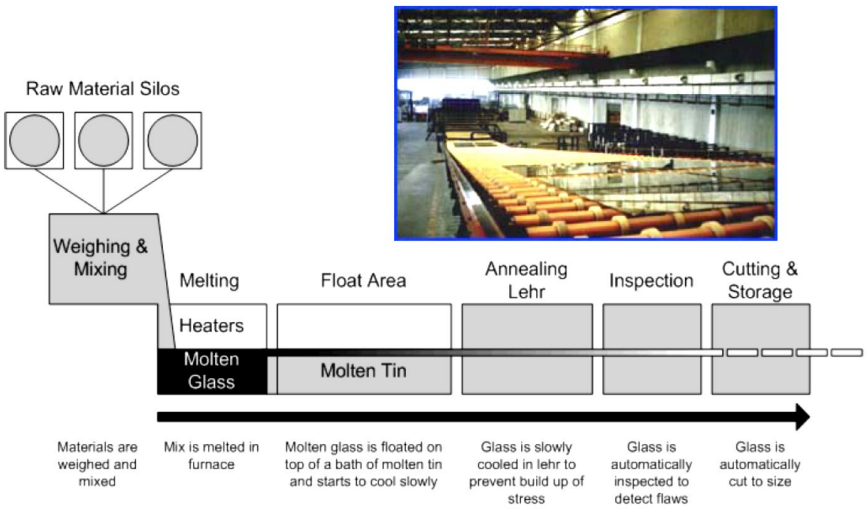

Figure 1 – Float glass forming process
Rajah 1 – Proses pembentukan kaca apungan

(b). The input/output of proportional controller is expressed through a linear equation. However, there is a limit on how much the controller output can grow. State why this happens and how to overcome this issue.

Kemasukan/keluaran kawalan perkadaran dihubungkan secara persamaan linear. Namun begitu terdapat had dimana jumlah pengeluaran kawalan dapat ditingkatkan. Nyatakan mengapakah perkara ini terjadi dan bagaimana masalah ini mampu diatasi.

(6 marks/*markah)*

(c). A derivative controller has a gain of 15 s. Compute the controller output if the controller is subjected to a constant error of 5.

Suatu pengawal jenis kebezaan mempunyai nilai kenaikan sebanyak 15 s.Tentukan nilai keluaran kawalan jika pengawal dikenakan ralat pekali sebanyak 5.

(4 marks/*markah)*

PART B / *BAHAGIAN B*

(2). An assessment of statistical stability of an extrusion process to produce a plastic tubing needs to be established. The inner diameter of tubing is an important functional parameter of the part. The values given in Table 1 are in mm.

Penilaian kestabilan statistik proses penyemperitan untuk menghasilkan tiub plastik perlu diwujudkan. Diameter dalaman tiub adalah parameter fungsian yang penting. Nilai yang diberikan dalam Jadual 1 adalah dalam mm.

Table 1: Inner diameter of plastic tubing

Jadual 1: Diameter dalaman tiub plastik

Sample number/ *Nombor sampel*	**X_1**	**X_2**	**X_3**	**X_4**	**X_5**	$\bar{X}$	**R**
1	91.5	89.1	92.0	89.0	91.6	90.6	3.0
2	90.0	90.5	91.1	86.2	89.8	89.5	4.9
3	90.5	88.9	90.2	87.3	91.5	89.7	4.2
4	87.1	93.0	88.2	91.3	90.0	89.9	5.9
5	94.0	89.0	90.9	91.5	89.5	91.0	5.0
6	91.2	89.5	90.2	89.6	89.2	89.9	2.0
7	91.1	89.4	90.6	90.2	89.6	90.2	1.7
8	89.7	93.3	87.9	88.5	90.0	89.9	5.4
9	92.8	92.6	92.0	89.5	92.2	91.8	3.3
10	89.0	90.1	89.3	93.1	90.3	90.4	4.1
11	89.5	92.5	90.8	93.3	89.6	91.1	3.8
12	90.2	89.4	89.2	89.9	89.3	89.6	1.0
13	90.6	87.2	92.3	90.9	90.4	90.3	5.1
14	91.2	90.3	92.2	89.6	90.3	90.7	2.6
15	90.6	89.3	91.3	92.5	91.1	91.0	3.2
16	90.7	90.9	90.4	92.3	88.8	90.6	3.5
17	91.3	90.9	91.2	92.8	91.6	91.6	1.9
18	88.9	91.3	89.9	91.3	88.6	90.0	2.7
19	91.3	90.9	91.2	92.3	91.6	91.5	1.4
20	90.4	89.7	91.6	91.6	92.3	91.1	2.6

(a). Calculate the centre value, upper control limit and lower control limit for R-chart and $\bar{X}$-chart. The constants of control charts are given in Appendix 1.

Kirakan nilai pertengahan, had kawalan atas dan had kawalan bawah bagi carta-R dan carta-$\bar{X}$. Pemalar-pemalar bagi carta kawalan diberi dalam Apendiks 1.

(6 marks/*markah*)

(b). Construct the R-chart and $\bar{X}$-chart.
Binakan carta-R dan carta-$\bar{X}$.

(10 marks/*markah*)

(c). If there is an outlier, describes action should be taken on both the charts.
Sekiranya terdapat titik luar, terangkan tindakan yang perlu diambil bagi kedua-dua carta tersebut.

(4 marks/*markah*)

(3). (a). Elucidate three control objectives that can be achieved through process control, using the float glass forming process illustrated in Figure 1 as an example.

Jelaskan tiga objektif kawalan yang boleh dicapai melalui kawalan proses dengan menggunakan proses pembentukan kaca apungan yang digambarkan dalam Rajah 1 sebagai contoh.

(9 marks/*markah*)

(b). Figure 2 shows the block diagram of a heat exchanger system. Find the equivalent transfer function, *T(s) = C(s)/ R(s)* using

Rajah 2 merupakan gambarajah blok bagi sebuah sistem kawalan penukaran. Tentukan fungsi pindah yang seiring, T(s) = C(s)/ R(s) dengan menggunakan

(i). Block diagram reduction rules, and
Peraturan penurunan gambarajah blok, dan

(ii). Mason's gain rule.
Peraturan gandaan Mason.

(11 marks/*markah*)

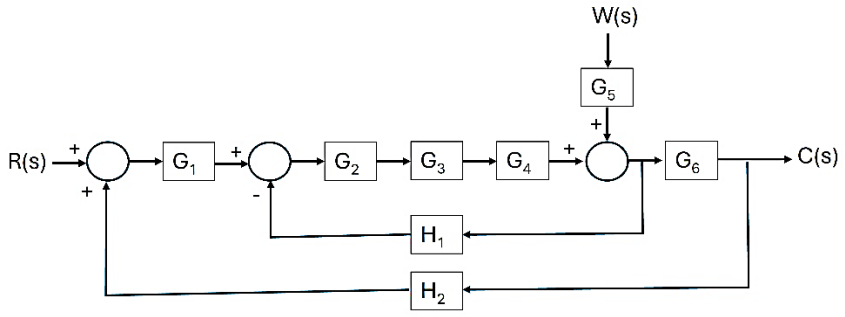

Figure 2 – Block diagram of a heat exchanger system.
Rajah 2 – Gambarajah blok bagi sebuah sistem penukaran haba.

(4). (a). Define transfer function of a linear time invariant system.
Takrifkan fungsi pindah bagi suatu sistem linear masa tak berubah

(2 marks/*markah*)

(b). Derive Laplace Transform for below function.
Terbitkan Transformasi Laplace untuk fungsi di bawah.

(i) $f(t) = u(t) + 2t + 3t^2$

(3 marks/*markah*)

(ii) $f(t) = u(t) + e^{-2t} - 2e^{-t}$

(3 marks/*markah*)

(c). Find the transfer function, G(s) = $V_L(s)/V(s)$ for each of electrical network shown in Figure 3.

Cari fungsi pemindahan, G(s) = $V_L(s)/V(s)$ untuk setiap rangkaian elektrik yang ditunjukkan dalam Rajah 3.

(12 marks/*markah*)

(i) (ii)

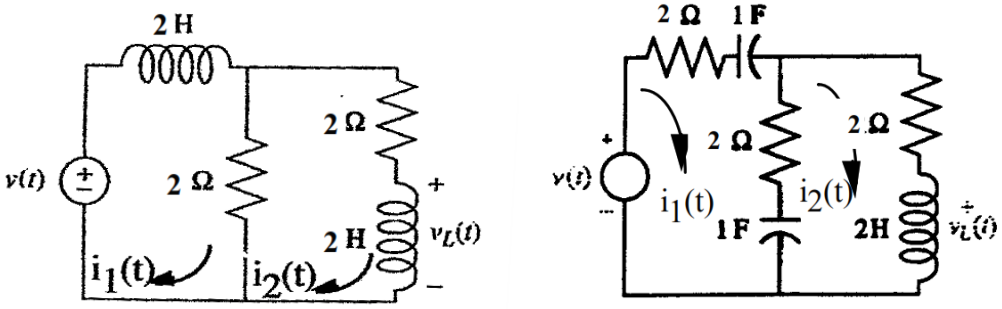

Figure 3 – Schematic of electrical network
Rajah 3 - Skematik bagi rangkaian elektrik

PART C / *BAHAGIAN C*

(5). (a). Sketch and analyze the root locus for the following open loop transfer function.

Lakar dan analisis londar punca bagi rangkap pindah gelung buka berikut.

(14 marks/*markah)*

$$GH = \frac{s+6}{s(s^2+8s+15)}$$

(b). Given the characteristic equation for a system control is $S^3 + 2S^2 + 2S + 13 = 0$. Verify the stability of the system by determining the roots of the characteristic equation.

Diberikan persamaan pencirian bagi suatu sistem kawalan adalah $S^3 + 2S^2 + 2S + 13 = 0$. Tentusahkan kestabilan sistem ini dengan mencari nilai punca-punca kepada persamaan pencirian tersebut.

(6 marks/*markah)*

(6). (a). Given the characteristic equation:

$2S^4 + 8S^3 + 12S^2 + 8S + 2(1 + K) = 0$

Compute the value of K so that the system is unstable.

Diberi persamaan cirian:

$2S^4 + 8S^3 + 12S^2 + 8S + 2(1 + K) = 0$

Kirakan nilai untuk K supaya sistem berada dalam keadaan tak stabil.

(8 marks/*markah)*

(b). Using R-H criterion, analyze and identify how many poles there are on the right half plane for the following characteristic equation. Write the comment on the stability of this system.

$$Q(s) = S^6 + 4S^5 + 3S^4 + 2S^3 + S^2 + 4S + 4 = 0$$

Dengan menggunakan kriteria R-H, lakukan analisa dan kenalpasti berapakah bilangan kutub pada satah sebelah kanan bagi persaman cirian berikut. Tuliskan komen tentang kestabilan sistem ini.

(8 marks/*markah)*

(c). Briefly explain the significant of *BIBO* concept in process control.
Terangkan secara ringkas kepentingan konsep BIBO di dalam kawalan proses.

(4 marks/*markah)*

(7). (a). State the general characteristics of overdamped respons for second order system
Nyatakan ciri-ciri umum sambutan teredam lebih bagi sistem tertib kedua.

(4 marks/*markah)*

(b). Derive the mathematical equation for rise time and settling time for first order system.

Terbitkan persamaan matematik bagi masa naik dan masa penetapan untuk sistem tertib pertama.

(8 marks/*markah)*

(c). For first oder system, THREE (3) value of parameter *(a)* was suggested (0.4,0.5 and 0.6). From your opinion, which one will give the best performance from transient response point of view. Explain your answer

Untuk suatu sistem tertib pertama, TIGA (3) nilai parameter (a) telah dicadangkan (0.4,0.5 dan 0.6). Pada pandangan anda, nilai yang manakah akan menghasilkan prestasi terbaik dari sudut pandangan tindak balas fana. Terangkan jawapan anda.

(8 marks/markah)

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Appendix 1 Constants of control charts

Apendiks 1 Pemalar bagi carta kawalan

iability	X bar and R Charts				X bar and s charts			
	Chart for Averages	Chart for Ranges (R)			Chart for Averages	Chart for Standard Deviation (s)		
	Control Limits Factor	Divisors to Estimate σ_x	Factors for Control Limits		Control Limits Factor	Divisors to estimate σ_x	Factors for Control Limits	
Subgroup size (n)	A_2	d_2	D_3	D_4	A_3	c_4	B_3	B_4
2	1.880	1.128	-	3.267	2.659	0.7979	-	3.267
3	1.023	1.693	-	2.574	1.954	0.8862	-	2.568
4	0.729	2.059	-	2.282	1.628	0.9213	-	2.266
5	0.577	2.326	-	2.114	1.427	0.9400	-	2.089
6	0.483	2.534	-	2.004	1.287	0.9515	0.030	1.970
7	0.419	2.704	0.076	1.924	1.182	0.9594	0.118	1.882
8	0.373	2.847	0.136	1.864	1.099	0.9650	0.185	1.815
9	0.337	2.970	0.184	1.816	1.032	0.9693	0.239	1.761
10	0.308	3.078	0.223	1.777	0.975	0.9727	0.284	1.716
15	0.223	3.472	0.347	1.653	0.789	0.9823	0.428	1.572
25	0.153	3.931	0.459	1.541	0.606	0.9896	0.565	1.435

	Centerline	Control Limits		σ_x
X bar and R Charts	$CL_{\overline{X}} = \overline{\overline{X}}$	$UCL_{\overline{X}} = \overline{\overline{X}} + A_2\overline{R}$	$LCL_{\overline{X}} = \overline{\overline{X}} - A_2\overline{R}$	$\frac{\overline{R}}{d_2}$
	$CL_R = \overline{R}$	$UCL_R = D_4\overline{R}$	$LCL_R = D_3\overline{R}$	
X bar and s Charts	$CL_{\overline{X}} = \overline{\overline{X}}$	$UCL_{\overline{X}} = \overline{\overline{X}} + A_3\overline{S}$	$LCL_{\overline{X}} = \overline{\overline{X}} - A_3\overline{S}$	$\frac{\overline{s}}{c_4}$
	$CL_s = \overline{s}$	$UCL_s = B_4\overline{s}$	$LCL_s = B_3\overline{s}$	

Appendix 2 Laplace Transform

Apendiks 2 Tansformasi Laplace

F(s)	f(t)
$\frac{a}{s}$	a, or au(t)
$\frac{a}{s^2}$	at
$\frac{1}{(s+a)}$	e^{-at}
$\frac{\omega}{(s^2+\omega^2)}$	$\sin \omega t$
$\frac{s}{(s^2+\omega^2)}$	$\cos \omega t$
$\frac{\omega}{(s+a)^2+\omega^2}$	$e^{-at} \sin \omega t$
$\frac{s+a}{(s+a)^2+\omega^2}$	$e^{-at} \cos \omega t$
$s^2F(s) - sf(0) - f'(0)$	$\frac{d^2f}{dt^2}$
$\frac{F(s)}{s}$	$\int_0^t f(t)\, dt$
$e^{-st_o}F(s)$	$f(t - t_o)$
A	$A\delta(t)$