UNIVERSITI SAINS MALAYSIA

First Semester Examination
2012/2013 Academic Session

January 2013

EKC 361 – Process Dynamics and Control
[Proses Dinamik dan Kawalan]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of SEVEN pages of printed material and ONE pages of Appendix before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi TUJUH muka surat yang bercetak dan SATU muka surat Lampiran sebelum anda memulakan peperiksaan ini.]

Instruction: Answer **ALL** (4) questions.

*[**Arahan:** Jawab **SEMUA** (4) soalan.]*

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

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

Answer ALL questions.
Jawab SEMUA soalan.

1. The jacketed heat exchanger in Figure Q.1. below is to be modeled. The input variable is T_0* and the output variable is T*. The inlet coolant temperature is constant. The following assumptions may be made;

Penukar haba berjaket dalam Rajah S.1. di bawah perlu dimodelkan. Pembolehubah masukan adalah T_0* *dan pembolehubah keluaran adalah* T*. *Suhu bahan pendingin masukan adalah malar. Andaian-andaian di bawah boleh dibuat;*

i. both vessel are well mixed.
kedua-dua tangki bercampur dengan lengkapnya.

ii. physical properties are constant.
ciri-ciri fizikal adalah malar.

iii. flows and volumes are constant.
kadar-kadar aliran dan isipadu-isipadu adalah malar.

iv. $Q=UA(T-T_c)$

v. the dynamic balances on *both* volumes must be solved simultaneously.
imbangan dinamik bagi kedua-dua isipadu mesti diselesaikan secara serentak.

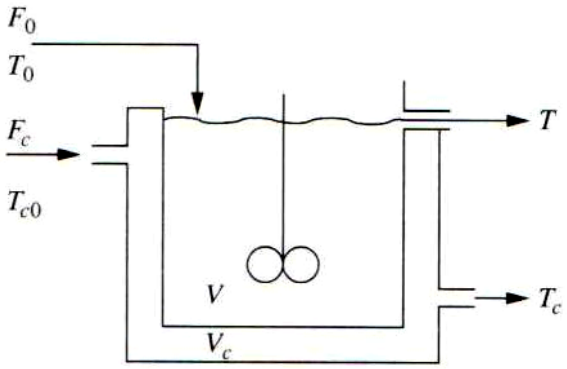

Figure Q.1.
Rajah S.1.

[a] Write the basic balances for both volumes in deviation variables (in time domain).
Tuliskan imbangan-imbangan asas bagi kedua-dua isipadu dalam bentuk pembolehubah lencongan (dalam domain masa).

[6 marks/markah]

[b] Put the model equations obtained in [a] in standard form of equation.
Bentukkan persamaan model yang diperolehi di [a] dalam bentuk persamaan piawai.

[2 marks/markah]

…3/-

[c] Take the Laplace transforms of the model obtained in [b].
Ubahkan model yang diperolehi dalam [b] menggunakan penjelmaan Laplace.

[4 marks/markah]

[d] Combine into the transfer function $T^*(s)/T_0^*(s)$.
Gabungkan ke rangkap pindah $T^*(s)/T_0^*(s)$.

[5 marks/markah]

[e] Analyze this result to determine whether the dynamic behavior is stable and periodic based on the *Complex 's' Plane* plot.
Analisa keputusan yang diperolehi untuk menentukan sama ada kelakuan dinamik adalah stabil dan berkala berdasarkan kepada plot 'Complex 's' Plane'.

[4 marks/markah]

[f] Briefly explain what are the properties can be determined from the transfer functions obtained.
Terangkan secara ringkas ciri-ciri yang boleh ditentukan daripada rangkap pindah yang diperolehi.

[4 marks/markah]

2. Figure Q.2.1. shows a home temperature control system.
Rajah S.2.1. menunjukkan sebuah sistem kawalan suhu rumah.

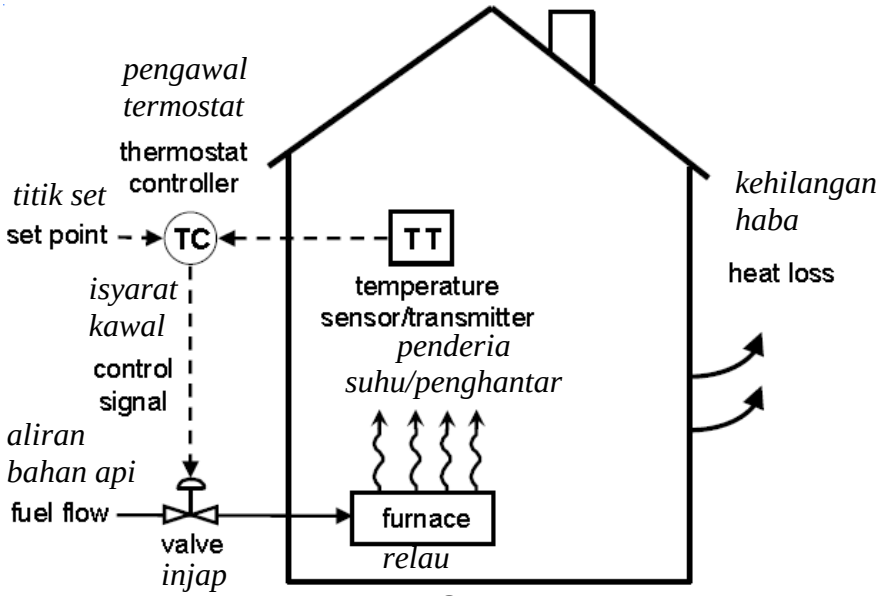

Figure Q.2.1.
Rajah S.2.1

[a] Based on Figure Q.2.1, identify the following variables
Berdasarkan Rajah S.2.1, kenalpasti pembolehubah-pembolehubah berikut:

[i] Control Objective
Objektif Kawalan

[ii] Process Variable (PV)
Pembolehubah Proses

[iii] Controller Output (CO)
Keluaran Pengawal

[iv] Manipulated Variable (MV)
Pembolehubah Termanipuslasi

[v] Disturbances (D)
Gangguan

[5 marks/markah]

[b] The home temperature control system illustrated in Figure Q.2.1. can be described as a closed-loop control block diagram as shown in Figure Q.2.2. Replaced all the terms in the block diagram given in Figure Q.2.2. with the elements in Figure Q.2.1.

Sistem kawalan suhu rumah yang digambarkan dalam Rajah S.2.1. boleh digambarkan sebagai rajah blok gelung tertutup seperti Rajah S.2.2. Gantikan kesemua terma di dalam gambar yang diberikan dalam Rajah S.2.2. dengan elemen-elemen dalam Rajah S.2.1.

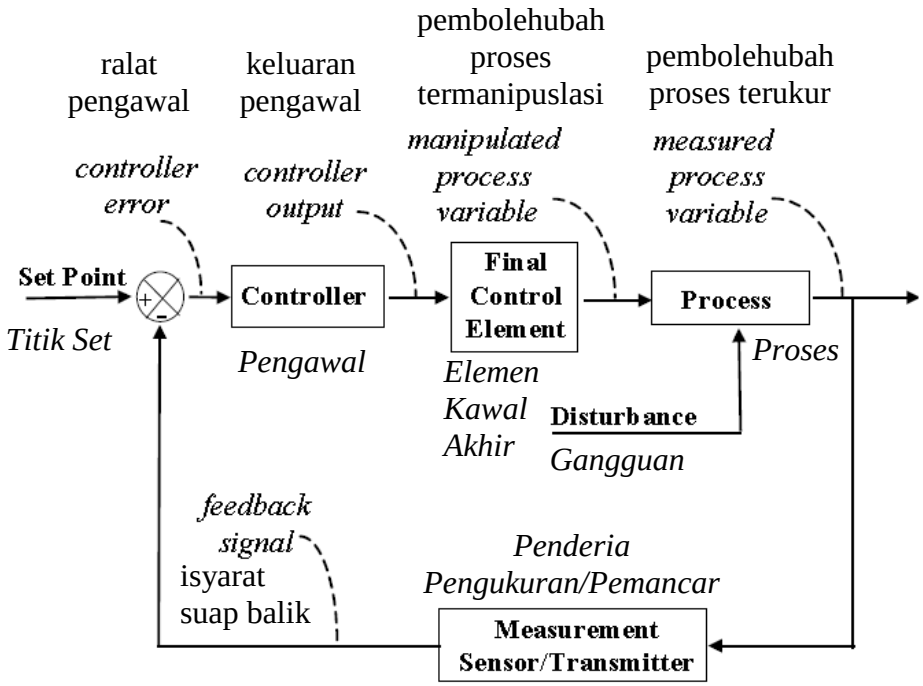

Figure Q.2.2.
Rajah S.2.2.

[5 marks/markah]

[c] You have been working all day and you came back home to have a good rest. Your house is equipped with a similar home temperature control system as shown in Figure Q.2.1. You felt that the temperature of the house is a bit warm to your liking. You have set the set point to your thermostat to a new temperature 10 °C below the current temperature. Describe how the home temperature control system reacts to the changes in the set point value. (Make sure you utilize all the elements shown in the Figure Q.2.1. in your description of the process).

Anda telah bekerja sepanjang hari dan anda balik ke rumah untuk mendapatkan rehat yang secukupnya. Rumah anda dilengkapi dengan sistem kawalan suhu rumah seperti yang ditunjukkan dalan Rajah S.2.1. Anda merasakan suhu rumah tersebut agak panas. Anda telah setkan titik set termostat kepada suhu baru 10 °C di bawah suhu terkini. Gambarkan bagaimana sistem kawalan suhu rumah anda bertindak balas kepada perubahan suhu pada nilai titik set. (Pastikan anda menggunakan kesemua elemen yang ditunjukkan di dalam Rajah S.2.1. dalam proses diskripsi anda).

[10 marks/markah]

[d] If all the control loop elements in Figure Q.2.2. represented by a first order system, redraw Figure Q.2.2. to represent such system (making sure all the elements of the closed-loop diagram is replaced with a 1st order system). What would be the overall transfer function of the home temperature control system?

Sekiranya kesemua elemen gelung kawalan di dalam Rajah S.2.2. diwakilkan dengan sistem tertib pertama, lukiskan kembali Rajah S.2.2. untuk mewakilkan sistem tersebut (pastikan kesemua elemen di dalam rajah gelung tertutup di gantikan dengan sistem tertib pertama). Apakah rangkap pindah keseluruhan bagi sistem kawalan suhu rumah tersebut?

[5 marks/markah]

3. Consider the closed loop block diagram of the feedback system shown in Figure Q.3. For a set point step change of magnitude 2.

Pertimbangkan gambarajah blok gelung tertutup untuk sistem suapbalik seperti yang ditunjukkan dalam Rajah S.3. Bagi tukar langkah titik set pada magnitud 2.

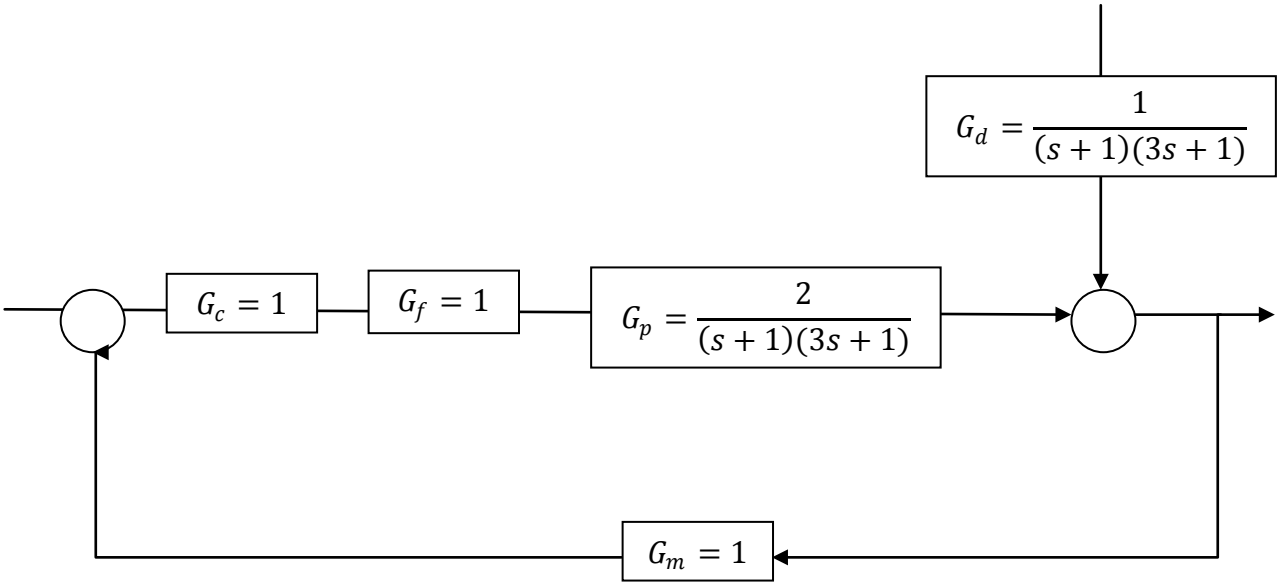

Figure Q.3.
Rajah S.3.

[a] Derive an expression for the closed loop response in the Laplace domain.
Terbitkan ungkapan sambutan gelung tertutup dalam domain Laplace.
[8 marks/markah]

[b] Find how the closed loop output responds with time to the set point step change above.
Carikan bagaimana keluaran gelung tertutup bertindak dengan masa apabila tukar langkah titik set dilakukan seperti di atas.
[4 marks/markah]

[c] Compute the maximum value of y(t) and state when it occurs.
Kirakan nilai maksimum y(t) dan tentukan ia bila berlaku.
[5 marks/markah]

[d] Compute the offset of the final steady state.
Kirakan ofset keadaan mantap akhir.
[2 marks/markah]

[e] Compute the period of oscillation of the closed loop response.
Kirakan tempoh ayunan bagi sambutan gelung tertutup tersebut.
[2 marks/markah]

[f] Give a qualitative sketch of the closed loop response.
Berikan lakaran kualitatif sambutan gelung tertutup tersebut.
[2 marks/markah]

[g] If K_c used is less than the value initially given, sketch the new closed loop response output on the same figure you drew for part [f] and indicate it in the figure.

Jika K_c yang digunakan adalah lebih rendah daripada nilai asal, lakarkan keluaran sambutan gelung tertutup yang baru dalam rajah yang sama untuk bahagian [f]. Tunjukkan ia dalam rajah tersebut.

[2 marks/markah]

4. Consider the following problem of a temperature control system.
Pertimbangkan masalah bagi sistem kawalan suhu berikut.

[a] The process reaction curve of the process gave the values
Lengkungan tindak balas proses bagi proses tersebut adalah

$K = 10$ $\tau = 2$ min $t_d = 0.1$ min

Compute the settings of a PID controller using the Cohen-Coon tuning methodology.
Kirakan set-set kawalan PID menggunakan kaedah penalaan Cohen-Coon.

[8 marks/markah]

[b] If the process is treated as a first order system, determine the amplitude ratio when it happens at corner frequency. Sketch the Bode diagram and indicate on the diagram the important parameters.

Jika proses ini dianggapkan sebagai sistem tertib pertama, tentukan nisbah amplitud apabila ia berlaku pada frekuensi sudut. Lakarkan gambarajah Bode dan tunjukkan parameter-parameter penting pada gambarajah tersebut.

[8 marks/markah]

[c] For only the proportional control, determine the setting using Ziegler-Nichols method. Compare to the value obtained if Cohen-Coon tuning method is used. State your observation.

Bagi kawalan berkadar sahaja, tentukan setnya menggunakan kaedah Ziegler-Nichols. Bandingkan nilai yang diperolehi jika kaedah penalaan Cohen-Coon digunakan. Nyatakan pemerhatian anda.

[9 marks/markah]

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Appendix

Table Laplace Transforms for Various Time-Domain Functions[a]

	$f(t)$	$F(s)$
1.	$\delta(t)$ (unit impulse)	1
2.	$S(t)$ (unit step)	$\frac{1}{s}$
3.	t (ramp)	$\frac{1}{s^2}$
4.	t^{n-1}	$\frac{(n-1)!}{s^n}$
5.	e^{-bt}	$\frac{1}{s+b}$
6.	$\frac{1}{\tau}e^{-t/\tau}$	$\frac{1}{\tau s+1}$
7.	$\frac{t^{n-1}e^{-bt}}{(n-1)!}$ $(n>0)$	$\frac{1}{(s+b)^n}$
8.	$\frac{1}{\tau^n(n-1)!}t^{n-1}e^{-t/\tau}$	$\frac{1}{(\tau s+1)^n}$
9.	$\frac{1}{b_1-b_2}(e^{-b_2t}-e^{-b_1t})$	$\frac{1}{(s+b_1)(s+b_2)}$
10.	$\frac{1}{\tau_1-\tau_2}(e^{-t/\tau_1}-e^{-t/\tau_2})$	$\frac{1}{(\tau_1 s+1)(\tau_2 s+1)}$
11.	$\frac{b_3-b_1}{b_2-b_1}e^{-b_1t}+\frac{b_3-b_2}{b_1-b_2}e^{-b_2t}$	$\frac{s+b_3}{(s+b_1)(s+b_2)}$
12.	$\frac{1}{\tau_1}\frac{\tau_1-\tau_3}{\tau_1-\tau_2}e^{-t/\tau_1}+\frac{1}{\tau_2}\frac{\tau_2-\tau_3}{\tau_2-\tau_1}e^{-t/\tau_2}$	$\frac{\tau_3 s+1}{(\tau_1 s+1)(\tau_2 s+1)}$
13.	$1-e^{-t/\tau}$	$\frac{1}{s(\tau s+1)}$
14.	$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
15.	$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
16.	$\sin(\omega t+\phi)$	$\frac{\omega\cos\phi+s\sin\phi}{s^2+\omega^2}$
17.	$e^{-bt}\sin \omega t$	$\frac{\omega}{(s+b)^2+\omega^2}$
18.	$e^{-bt}\cos \omega t$	$\frac{s+b}{(s+b)^2+\omega^2}$
	b, ω real	
19.	$\frac{1}{\tau\sqrt{1-\zeta^2}}e^{-\zeta t/\tau}\sin(\sqrt{1-\zeta^2}\,t/\tau)$ $(0\le\lvert\zeta\rvert<1)$	$\frac{1}{\tau^2s^2+2\zeta\tau s+1}$
20.	$1+\frac{1}{\tau_2-\tau_1}(\tau_1e^{-t/\tau_1}-\tau_2e^{-t/\tau_2})$ $(\tau_1\neq\tau_2)$	$\frac{1}{s(\tau_1 s+1)(\tau_2 s+1)}$
21.	$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta t/\tau}\sin[\sqrt{1-\zeta^2}\,t/\tau+\psi]$ $\psi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$, $(0\le\lvert\zeta\rvert<1)$	$\frac{1}{s(\tau^2s^2+2\zeta\tau s+1)}$
22.	$1-e^{-\zeta t/\tau}[\cos(\sqrt{1-\zeta^2}\,t/\tau)+\frac{\zeta}{\sqrt{1-\zeta^2}}\sin(\sqrt{1-\zeta^2}\,t/\tau)]$ $(0\le\lvert\zeta\rvert<1)$	$\frac{1}{s(\tau^2s^2+2\zeta\tau s+1)}$
23.	$1+\frac{\tau_3-\tau_1}{\tau_1-\tau_2}e^{-t/\tau_1}+\frac{\tau_3-\tau_2}{\tau_2-\tau_1}e^{-t/\tau_2}$ $(\tau_1\neq\tau_2)$	$\frac{\tau_3 s+1}{s(\tau_1 s+1)(\tau_2 s+1)}$
24.	$\frac{df}{dt}$	$sF(s)-f(0)$
25.	$\frac{d^nf}{dt^n}$	$s^nF(s)-s^{n-1}f(0)-s^{n-2}f^{(1)}(0)-\cdots-sf^{(n-2)}(0)-f^{(n-1)}(0)$
26.	$f(t-t_0)S(t-t_0)$	$e^{-t_0s}F(s)$

[a]Note that $f(t)$ and $F(s)$ are defined for $t\ge 0$ only.