UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2002/2003

Februari/Mac 2003

EKC 361 E – Dinamik Dan Kawalan Proses

Masa : 3 jam

Sila pastikan bahawa kertas peperiksaan ini mengandungi DUA BELAS mukasurat yang bercetak sebelum anda memulakan peperiksaan ini.

Kertas soalan ini mengandungi ENAM soalan. Jawab EMPAT soalan.
Jawab mana-mana DUA soalan dari Bahagian A dan mana-mana DUA soalan dari Bahagian B.

Pelajar dibenarkan menjawab semua soalan dalam Bahasa Inggeris ATAU Bahasa Malaysia ATAU kombinasi kedua-duanya..

...2/-

SECTION A Answer any TWO questions from this section.
BAHAGIAN A Jawab mana-mana DUA soalan dari bahagian ini.

1. [a] Solve the following differential equation for x(t) using Laplace transforms.

$$\frac{dx}{dt} + 2x = 4.5$$

with the initial condition x (0) = 4

[6 marks]

[b] A mercury thermometer which has been on a table for sometime, is registering the room temperature, reads 75°F. Suddenly, it is placed in a 400°F oil bath. The following data are obtained for the response of the thermometer.

Time, Sec.	Thermometer reading, °F
0	75
1	107
2.5	140
5	205
8	244
10	282
15	328
30	385

Estimate the value of the time constant of the thermometer.

[7 marks]

[c] Derive the transfer function relating the level of the liquid in tank 2, h_2, and the inlet flowrate, q, to tank 1, when the two tanks are connected in the non-interacting way, as shown in Figure Q.1.

Assume that the liquid is of constant density, the tanks to have uniform cross-sectional area and the flow resistances are linear. The flow-head relationship is given by the expression q = h/R.

[12 marks]

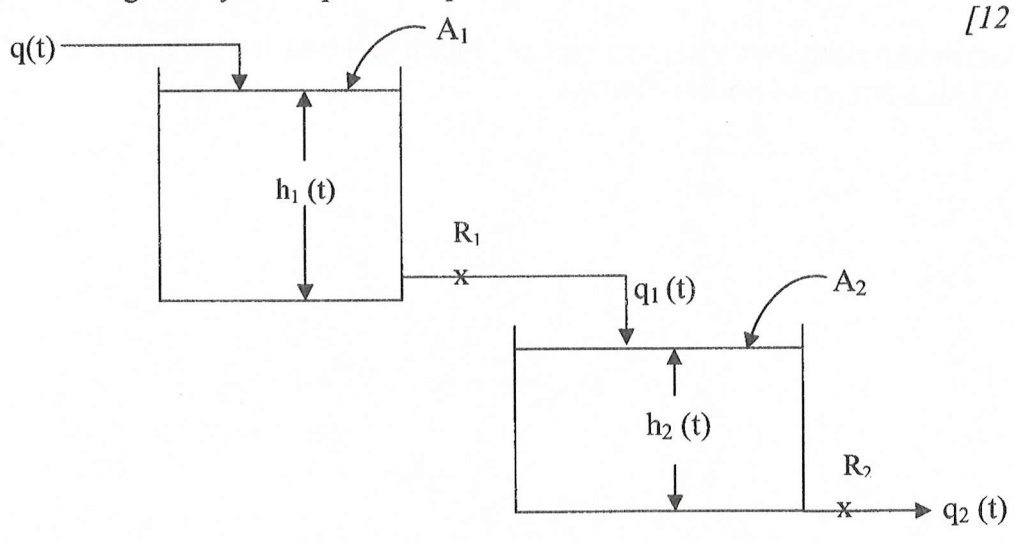


Figure Q.1

...3/-

1. [a] *Selesaikan persamaan kebezaan berikut untuk x(t) menggunakan Jelmaan Laplace.*

$$\frac{dx}{dt} + 2x = 4.5$$

dengan keadaan awal x(0) = 4

[6 markah]

[b] *Termometer merkuri yang sudah berada di atas meja untuk beberapa ketika, menunjukkan bacaan suhu bilik 75°F. Secara tiba-tiba, ia diletakkan di dalam mandian minyak 400°F. Berikut adalah data yang diperolehi dari respon termometer tersebut.*

Masa, saat.	*Bacaan termometer, °F*
0	*75*
1	*107*
2.5	*140*
5	*205*
8	*244*
10	*282*
15	*328*
30	*385*

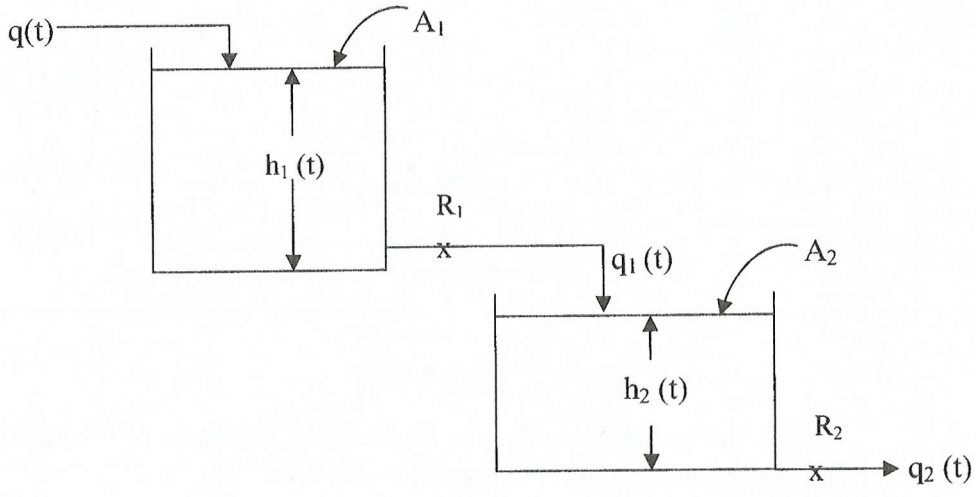
Anggarkan nilai pemalar masa termometer tersebut.

[7 markah]

[c] *Terbitkan rangkap pindah yang menghubungkan cecair di dalam tangki 2, h_2 dan kadar aliran masuk, q, ke dalam tangki 1, apabila dua tangki dirangkakan secara bukan saling tindakan seperti yang ditunjukkan dalam Rajah S. 1.*

Anggap cecair tersebut mempunyai ketumpatan malar, tangki-tangki tersebut mempunyai luas keratan rentas yang seragam dan rintangan aliran adalah linear. Hubungan aliran-ketinggian di berikan mengikut ungkapan q = h/R.

[12 markah]



Rajah S. 1

...4/-

2. [a] Consider a second-order system with the following transfer function.

$$G(s) = \frac{y(s)}{m(s)} = \frac{1}{s^2 + s + 1}$$

Introduce a step change of magnitude 5 into the system and find

[i] percent overshoot

[ii] decay ratio

[iii] ultimate value

[iv] maximum value of y(t)

[v] period of oscillation

The unit step response of an underdamped system is given by

$$\frac{y(t)}{k_p} = 1 - \frac{1}{\sqrt{1-\xi^2}} e^{-\xi t/\tau} \sin(\omega t + \phi)$$

where $\omega = \frac{\sqrt{1-\xi^2}}{\tau}$ rad/time

$$\phi = \tan^{-1}\left[\frac{\sqrt{1-\xi^2}}{\xi}\right]$$

$$Overshoot = exp\left(-\Pi\xi/\sqrt{1-\xi^2}\right)$$

[12 marks]

[b] Define the servo- and the regulator problem.

[5 marks]

[c] Consider the following block diagram of a control system shown in Figure Q. 2.

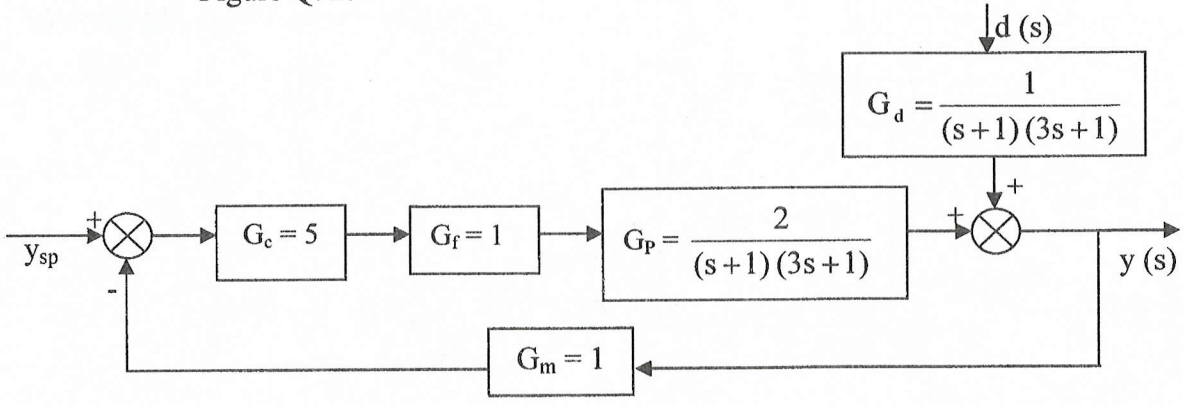


Figure Q. 2

Derive the expressions for the closed-loop response of the control system for the servo problem and the regulator problem.

[8 marks]

...5/-

2. [a] *Timbangkan sistem tertib kedua yang mempunyai rangkap pindah berikut.*

$$G(s)=\frac{y(s)}{m(s)}=\frac{1}{s^2+s+1}$$

Apabila tukar langkah yang bermagnitud 5 dikenakan kepada sistem, cari

[i] *peratus terlajak*

[ii] *nisbah susut*

[iii] *nilai muktamad*

[iv] *nilai maksimum y(t)*

[v] *tempoh ayunan*

Respon unit langkah untuk sistem terendam kurang diberikan sebagai

$$\frac{y(t)}{k_p}=1-\frac{1}{\sqrt{1-\xi^2}}e^{-\xi t/\tau}\sin(\omega t+\phi)$$

$$\text{di mana}\quad \omega=\frac{\sqrt{1-\xi^2}}{\tau}\ \text{rad/masa}$$

$$\varphi=\tan^{-1}\left[\frac{\sqrt{1-\xi^2}}{\xi}\right]$$

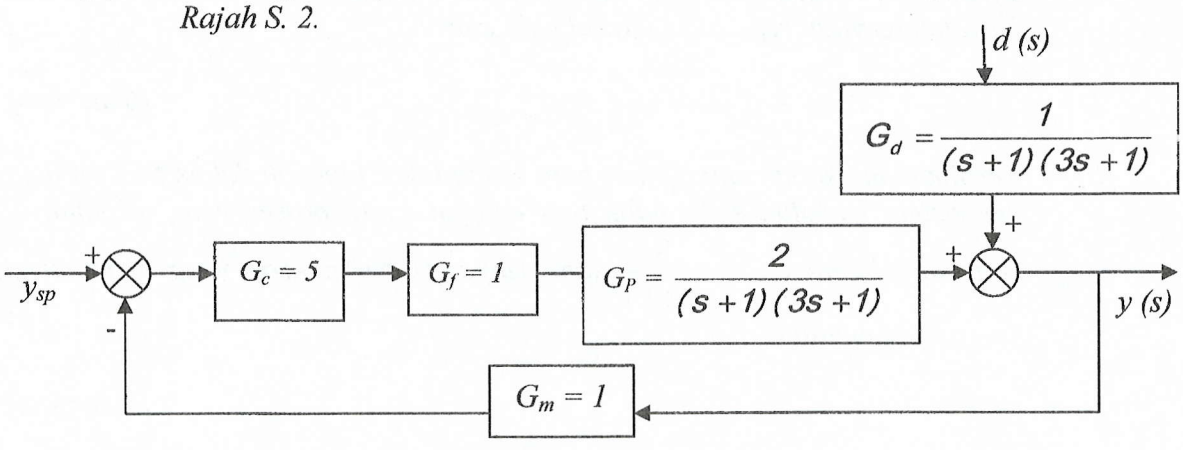
$$\text{Terlajak}=\exp\left(-\Pi\xi/\sqrt{1-\xi^2}\right)$$

[12 markah]

[b] *Takrif masalah servo- dan pengatur*

[5 markah]

[c] *Timbangkan rajah blok berikut untuk sistem kawalan yang ditunjukkan dalam Rajah S. 2.*



Rajah S. 2

...6/-

Terbitkan ungkapan untuk sambutan gelung tertutup bagi sistem kawalan untuk masalah servo dan masalah pengatur.

[8 markah]

3. [a] Explain the motivation of the addition of integral and derivative control modes to a proportional controller.

[6 marks]

[b] Derive an expression for offset of a unit step change in set point in the case of a unity feedback control system with a process whose transfer function is $G_P = \frac{K}{\tau s + 1}$ and a proportional controller with $G_c = K_c$. Assume $G_f = 1$.

[9 marks]

[c] Write the characteristic equation and construct the Routh array for the control system shown in Figure Q. 3. Is the system stable for (i) $K_c = 9.5$, (ii) $K_c = 11$ and (iii) $K_c = 12$?

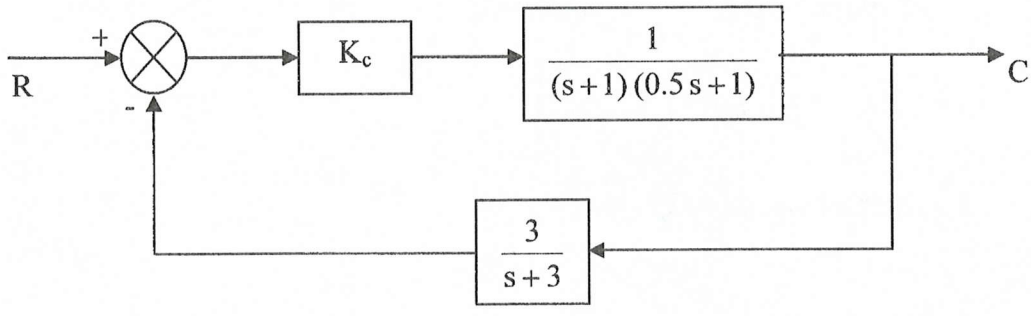


Figure Q. 3

[10 marks]

3. *[a] Terangkan rangsangan bagi penambahan mod-mod kawalan kamiran dan kawalan terbitan kepada pengawal berkadaran.*

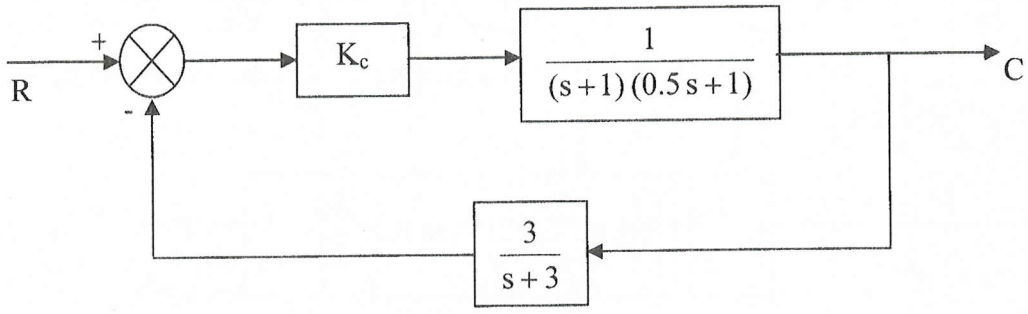
[6 markah]

[b] Terbitkan ungkapan untuk offset bagi seunit tukar langkah dalam titik set bagi kes sistem kawalan suap balik unit dengan suatu proses yang mempunyai rangkap pindah $G_P = \frac{K}{\tau s + 1}$ *dan pengawal berkadaran yang mempunyai* $G_c = K_c$. *Anggap* $G_f = 1$.

[9 markah]

...7/-

[c] Tulis persamaan ciri dan bina tatasusunan Routh untuk sistem kawalan seperti yang ditunjukkan dalam Rajah S. 3. Adakah sistem stabil bagi (i) $K_c = 9.5$, (ii) $K_c = 11$ dan (iii) $K_c = 12$?



Rajah S.3

[10 markah]

SECTION B Answer any TWO questions from this section.
BAHAGIAN B Jawab mana-mana DUA soalan dari bahagian ini.

4. [a] Briefly explain the following:-

[i] Static and dynamic error

[ii] Transmitter and transducer

[iii] Thermocouple

[iv] Thermal conductivity analyzer

[20 marks]

[b] Sketch a typical distillation column with its controlled and manipulated variables.

[5 marks]

4. [a] Terangkan secara ringkas perkara berikut:-

[i] Ralat statik dan dinamik

[ii] Pengantar dan transduser

[iii] Pengganding suhu

[iv] Penganalisis keberaliran haba

[20 markah]

[b] Lakar satu turus penyulingan biasa dengan pembolehubah kawalan dan pengolahnya

[5 markah]

...8/-

5. A process stream is heated using a shell and tube heat exchanger (Figure Q. 5). The exit temperature is controlled by adjusting steam control valve.

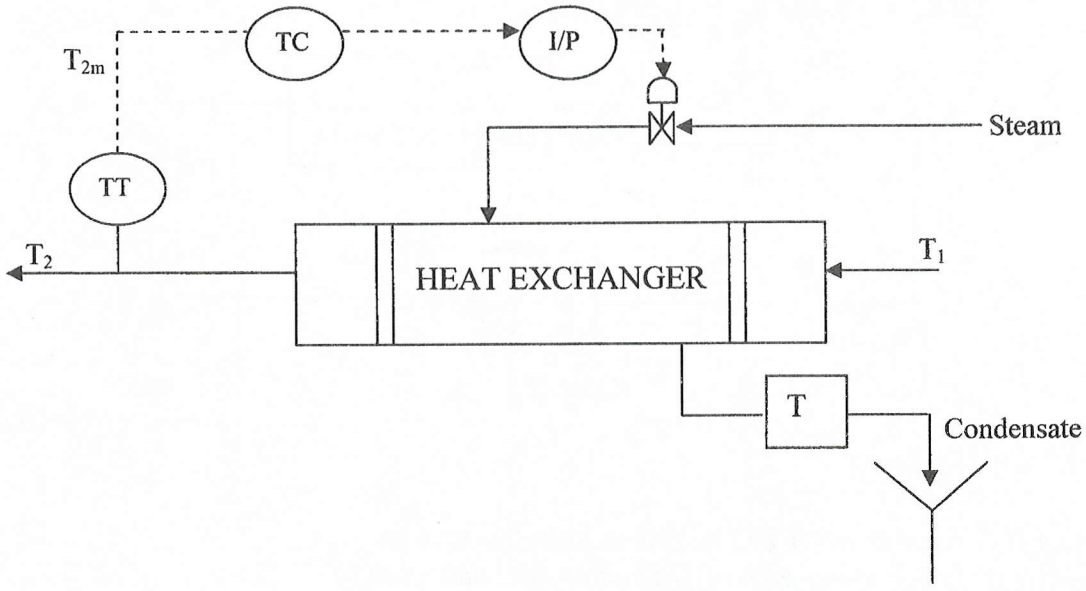


Figure Q. 5 : Shell and tube heat exchanger

During an open-loop experimental test, the steam pressure P_s was suddenly changed from 18 to 20 psig and the temperature data below were obtained

t (min)	T_{2m} (mA)
0	12.0
1	12.0
2	12.5
3	13.1
4	14.0
5	14.8
6	15.4
7	16.1
8	16.4
9	16.8
10	16.9
11	17.0
12	16.9

$K_V = 0.9$ psi/psi
$K_{IP} = 0.75$ psi/mA

[a] Plot this data to obtain a process reaction curve

[6 marks]

[b] Estimate the open-loop transfer function as a first order system with model parameters K_P, T and T_d.

[12 marks]

...9/-

[c] Using Cohen and Coon tuning rules obtain controller settings for PI and PID controllers for this system.

[7 marks]

PI :

$$K_c = \frac{1}{K_P}\frac{T}{T_d}\left(\frac{9}{10}+\frac{T_d}{12T}\right)$$

$$\tau_I = T_d\,\frac{30+3T_d/T}{9+20T_d/T}$$

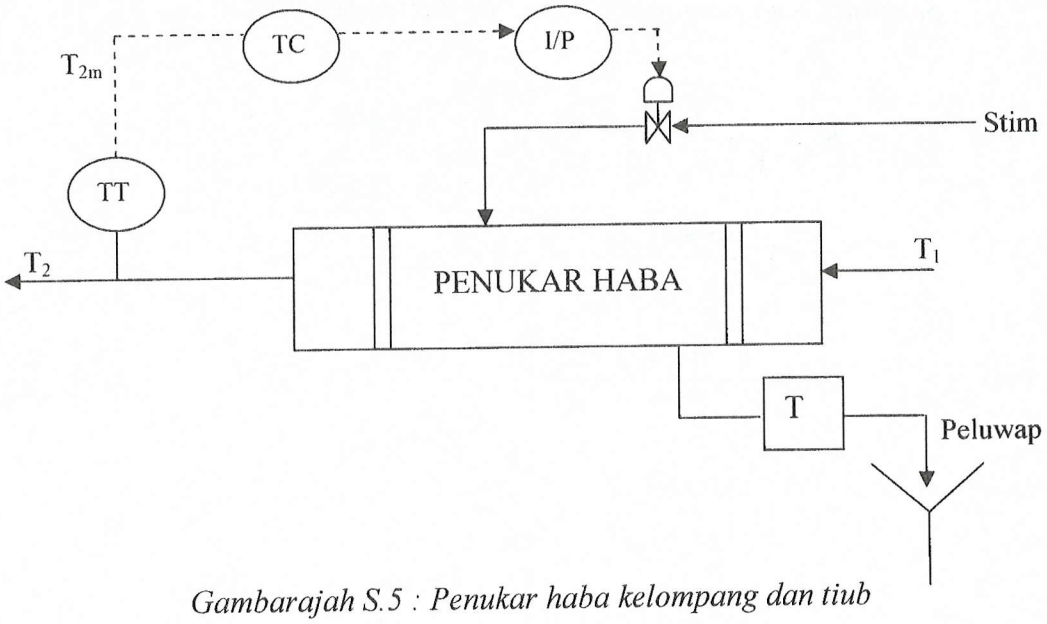
PID :

$$K_c = \frac{1}{K_P}\frac{T}{T_d}\left(\frac{4}{3}+\frac{T_d}{4T}\right)$$

$$\tau_I = T_d\,\frac{32+6T_d/T}{13+8T_d/T}$$

$$\tau_D = T_d\,\frac{4}{11+2T_d/T}$$

5. *Satu alur proses dipanaskan menggunakan penukar haba kelompang dan tiub (Gambarajah S.5). Suhu keluar dikawal dengan melaras injap kawalan stim.*



Gambarajah S.5 : Penukar haba kelompang dan tiub

...10/-

Semasa ujian eksperimen gelung-buka tekanan stim, P_s diubah secara mendadak daripada 18 kepada 20 psig dan data suhu di bawah diperolehi:-

t (min)	*T_{2m} (mA)*
0	*12.0*
1	*12.0*
2	*12.5*
3	*13.1*
4	*14.0*
5	*14.8*
6	*15.4*
7	*16.1*
8	*16.4*
9	*16.8*
10	*16.9*
11	*17.0*
12	*16.9*

K_V = 0.9 psi/psi
K_{IP} = 0.75 psi/mA

[a] *Plot data tersebut untuk mendapatkan lengkung tindakbalas proses.*

[6 markah]

[b] *Anggarkan fungsi pindah gelung-buka sebagai sistem tertib pertama dengan parameter model K_P, T dan T_d.*

[12 markah]

[c] *Dengan menggunakan kaedah talaan Cohen dan Coon, dapatkan set pengawal bagi pengawal PI dan PID bagi sistem ini.*

[7 markah]

PI :
$$K_c = \frac{1}{K_P}\frac{T}{T_d}\left(\frac{9}{10}+\frac{T_d}{12T}\right)$$

$$\tau_I = T_d\,\frac{30+3T_d/T}{9+20T_d/T}$$

PID :
$$K_c = \frac{1}{K_P}\frac{T}{T_d}\left(\frac{4}{3}+\frac{T_d}{4T}\right)$$

$$\tau_I = T_d\,\frac{32+6T_d/T}{13+8T_d/T}$$

$$\tau_D = T_d\,\frac{4}{11+2T_d/T}$$

...11/-

6. Figure Q.6 shows a stirred-tank heat exchanger with cascade control:-

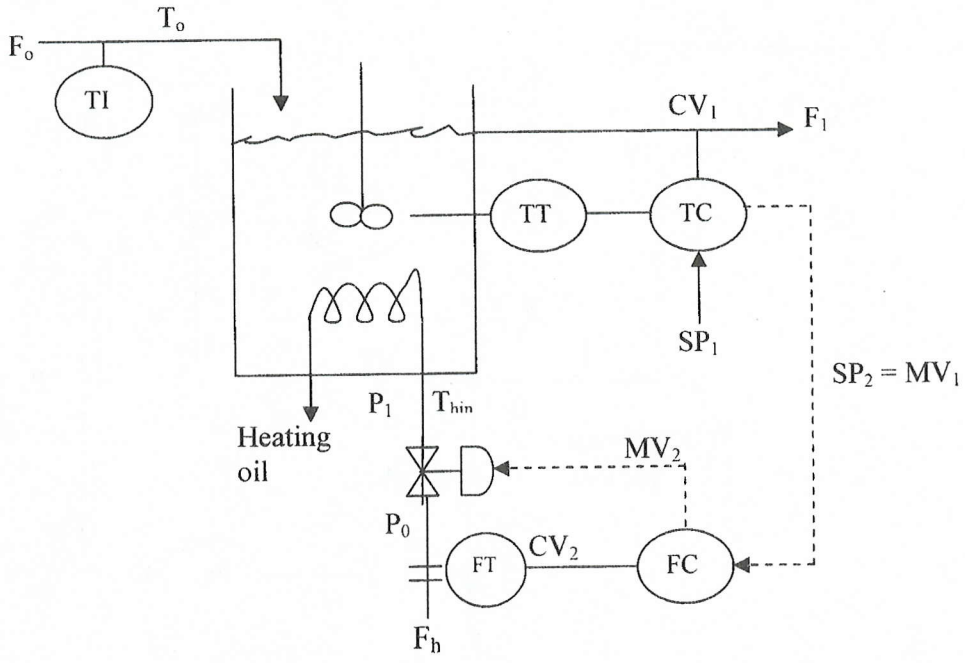


Figure Q. 6. : Stirred-tank heat exchanger with cascade control

where

CV = Controlled Variable

MV = Manipulated Variable

SP = Setpoint

[a] Draw a block diagram that presents the structure of the cascade control of the stirred-tank heat exchanger.

[6 marks]

[b] Derive transfer functions from the block diagram for the relationships between:-

[i] CV_1 and D_1 (Disturbance due to heating oil temperature, T_{hin})

[ii] CV_1 and D_2 (Disturbance due to inlet flow temperature, T_0)

[iii] CV_1 and SP_1

[12 marks]

[c] Redraw the stirred-tank heat exchanger but with:

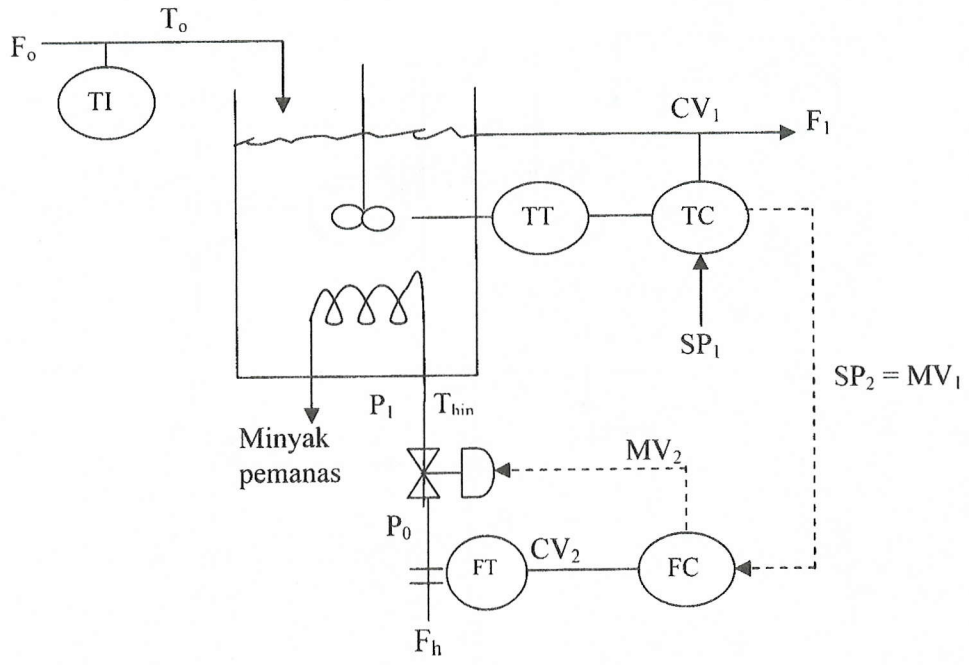
[i] feedforward control strategy

[ii] feedforward-feedback control strategy

[7 marks]

...12/-

6. *Gambarajah S. 6 menunjukkan tangki teraduk penukar haba dengan kawalan lata:-*



Gambarajah S. 6: Tangki teraduk penukar haba dengan kawalan lata.

di mana

CV = Pembolehubah Kawalan

MV = Pembolehubah Pengolah

SP = Titik set

[a] *Lukis gambarajah blok yang menunjukkan struktur kawalan lata bagi tangki teraduk penukar haba tersebut.*

[6 markah]

[b] *Terbitkan rangkap pindah daripada gambarajah blok bagi hubungan antara:-*

[i] *CV_1 dan D_1 (Gangguan disebabkan oleh suhu minyak pemanas, T_{hin})*

[ii] *CV_1 dan D_2 (gangguan disebabkan oleh suhu aliran masuk, T_0)*

[iii] *Cv_1 dan SP_1*

[12 markah]

[c] *Lukis semula tangki teraduk penukar haba tetapi dengan:-*

[i] *Strategi kawalan suap-depan*

[ii] *Strategi kawalan suap-depan-suap-balik*

[7 markah]

- ooo O ooo -