



UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF CHEMICAL AND BIO-ENGINEERING TECHNOLOGY

FINAL EXAMINATION
OCTOBER 2025 SEMESTER

COURSE CODE	:	CPB30004
COURSE TITLE	:	PROCESS DYNAMICS & CONTROL
PROGRAMME NAME	:	BACHELOR OF CHEMICAL ENGINEERING TECHNOLOGY (PROCESS) WITH HONOURS
DATE	:	03 FEBRUARY 2026
TIME	:	9:00AM - 12:00PM
DURATION	:	3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. This question paper consist of TWO sections.
4. Answer ALL questions for Section A.
5. Section B consist of four questions. Answer THREE (3) questions only.
6. Please write your answer on the answer booklet provided.
7. Please answer all questions in English only.
8. Please answer MCQ/EMQ questions using OMR sheet. ☐ *Tick if applicable*
9. Refer to the attached Formula/ Appendies. ☐ *Tick if applicable*

THERE ARE 8 PAGES OF QUESTIONS EXCLUDING FRONT PAGE & APPENDIXES

SECTION A (Total: 40 marks)

Answer ALL questions.

Please use the answer booklet provided.

Question 1

Process Dynamics fundamental is essential for any control to be implemented in any chemical process

- (a) List FIVE components involve in process control

(5 marks)

- (b) Label the components/parts according to the following figure :

Refer Below - Figure1 : Process variables .

(5 marks)

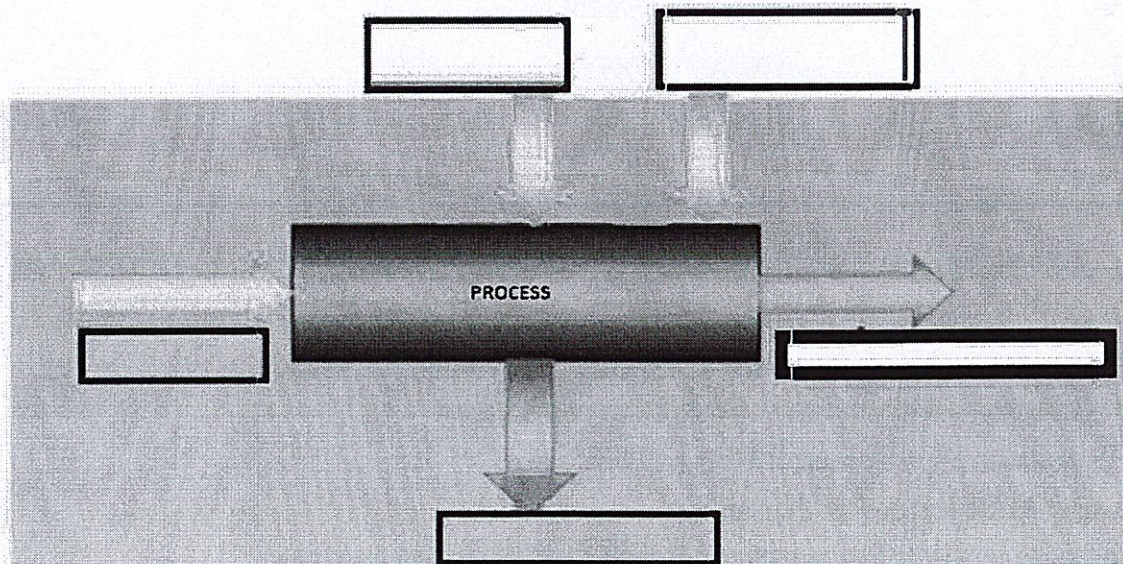


Figure 1: Process variables

Question 2

In process control solution a block diagram is needed to solve dynamics changes of the system

- (a) Draw basic components or blocks diagram of feedback system with correct arrangement of the following information: Final control element, controller, sensor / transmitter, comparator, controller. setpoint, disturbance, control loop

(6 marks)

- (b) The distillation column shown in Figure 2 is used to distill a binary mixture. Symbols x , y , and z denote mole fractions of the more volatile component, while B , D , R , and F represent molar flow rates. It is desired to control distillate composition y despite disturbances in feed flow rate F . All flow rates can be measured and manipulated with the exception of F , which can only be measured. A composition analyzer provides measurements of y . Propose a feedback control method for reflux and distillate product

Refer Below - Figure2 : The distillation column used to distill a binary mixture .

(4 marks)

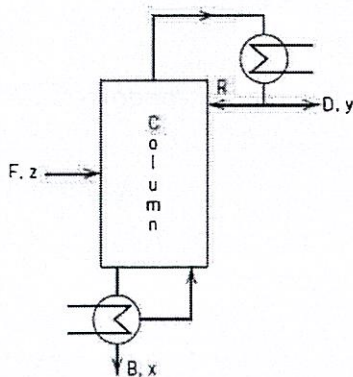


Figure 2: The distillation column used to distill a binary mixture

Question 3

Programmable logic controllers (PLCs) are simple digital devices that are widely used to control sequential and batch processes combining with microprocessor. PLCs can be utilized as standalone devices or in conjunction with digital computer control systems. Hughes (2005) and Lipták (2005) have summarized the general characteristics of PLCs

- (a) List **FOUR (4)** main functions of a PLC controller.

(4 marks)

- (b) Differentiate temporal control, state control, and hybrid control.

(6 marks)

Question 4

Distributed Control System (DCS) is a computerized, decentralized control architecture used in industrial plants, where, unlike centralized systems, functional controllers are distributed throughout the system rather than in one location. It manages large-scale, complex, and continuous processes.

- (a) List **FOUR(4)** the role of microprocessors in the evolution of modern DCS architectures

(4 marks)

- (b) State **FOUR(4)** typical hierarchical structure of a DCS.

(4 marks)

- (c) State main difference between logic and interlocking functions and continuous control in DCS.

(2 marks)

SECTION B (Total: 60 marks)

Answer THREE (3) questions only.

Please use the answer booklet provided.

Question 1

Find the Laplace transforms of the following functions, using the information in Table Laplace Transform. (However, some of the individual terms in these functions may not have Laplace transforms).

- (a) Solve Laplace Transform (3 marks)

$$f(t) = 5 + e^{-3t} + te^{-4t}$$

- (b) Solve Laplace Transform (5 marks)

$$f(t) = \sin(4t) + t - 3 + e^{-(t-3)} + \frac{5}{t}$$

- (c) Solve Laplace Transform (3 marks)

$$f(t) = e^{-t} \cos(4t) + \frac{t}{5}$$

- (d) Solve Laplace Transform (4 marks)

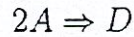
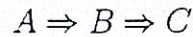
$$f(t) = (t - 1) \cos(4(t - 1)) + t^2$$

- (e) Find Inverse Laplace (5 marks)

$$X(s) = \frac{s(s + 1)}{(s + 2)(s + 3)(s + 4)}$$

Question 2

Figure 3 provides the schematic description of an isothermal continuously stirred tank reactor. It is assumed that the following reaction mechanism takes place in the reactor:



The inlet stream flow rate is given by F (l/hr) and the tank volume is denoted by V (l). We define $u = F/V$ as the dilution rate of the reactor (hr^{-1}). The reactant stream enters the reactor at a molar concentration C_{Ain} (mol/l). The reactor volume is denoted by V (l). The concentration of reactant A in the reactor is given by C_A (mol/l). The concentration of product B, C_B (mol/l), is to be controlled. It is assumed that all streams have the same density ρ and that flow is incompressible. It is also assumed that the inlet concentration in the reactant stream C_{Ain} and the reactor volume, V , are constant.

Refer Below- Figure3 : Isothermal Continuously Stirred Tank Reactor.

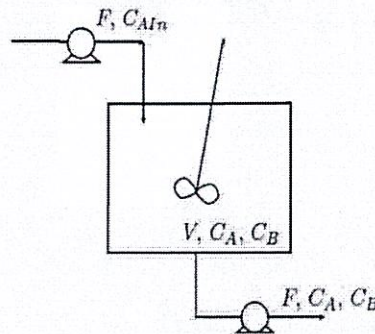


Figure 3: Isothermal Continuously Stirred Tank Reactor

The process dynamics are described by the following system of differential equations:

$$\begin{aligned} \frac{dC_A}{dt} &= -2C_A - C_A^2 + (C_{Ain} - C_A)u \\ \frac{dC_B}{dt} &= 2C_A - 2C_B - C_B u \end{aligned}$$

For this process, you are asked to perform the following:

- (a) Identify all inputs and outputs of the system. Classify inputs as disturbances or manipulated variables.

(5 marks)

- (b) For the choice of inputs and outputs, is the dynamical control system linear or nonlinear?

Solution:

(1 marks)

- (c) Consider the following operating conditions:

$$C_{Ain} = 1 \text{ (mol/l)}; u = 16 \text{ (hr}^{-1}\text{)}:$$

Compute the corresponding equilibrium conditions values for the reactor concentrations C_A and C_B .

(6 marks)

- (d) Linearize the system (if necessary) at the equilibrium computed in part c), express the linearized system in deviation form using Taylor series expansion

Hint: Find C_A first then C_B .

(8 marks)

Question 3

The blending tank shown in may be assumed to be perfectly mixed. The input variables are the solute concentrations and flows of the inlet streams, $c_1(t)$, $c_2(t)$ [kg/m³], $f_1(t)$, and $f_2(t)$ [m³/min]. The volume of liquid in the tank, V [m³], can be assumed constant, and variation of stream densities with composition may be neglected

Refer Below - Figure4 : Blending Tank .

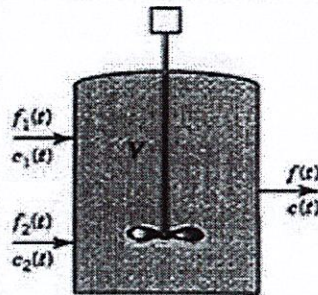


Figure 4: Blending Tank

- (a) Develop the variables diagram model of the system representing density and volume.

(5 marks)

- (b) Develop the steady state mathematical equation of the system. Use these assumption when build up the model:

- i. The fluid is ideally mixed, meaning that the concentration in the vessel is uniform. Only the dynamics in the order of magnitude of the residence time are considered. It is assumed that the mixing time constant is relatively small.
- ii. Energy effects do not play a role, neither owing to slight temperature differences of the flows, nor owing to the heat of mixing..
- iii. The compounds A and B have similar densities. The density of the mixture depends linearly on the volume fractions of both components

(5 marks)

- (c) Obtain the transfer functions for the outlet composition $C(s)$, kg/m³, and outlet flow $F(s)$, m³/min, to the four input variables, and write the expressions for the time constant and gains of the blender in terms of the parameters of the system.

(10 marks)

Question 4

The reactor control configuration shown in Figure 5 below utilizes a measurement of the cooling water temperature. It has been suggested that the temperature of the reactor wall be measured to deal with temperature gradients in the tank contents, a so-called triple cascade control loop.

Refer Below - Figure5 : Cascade control of an exothermic chemical reactor .

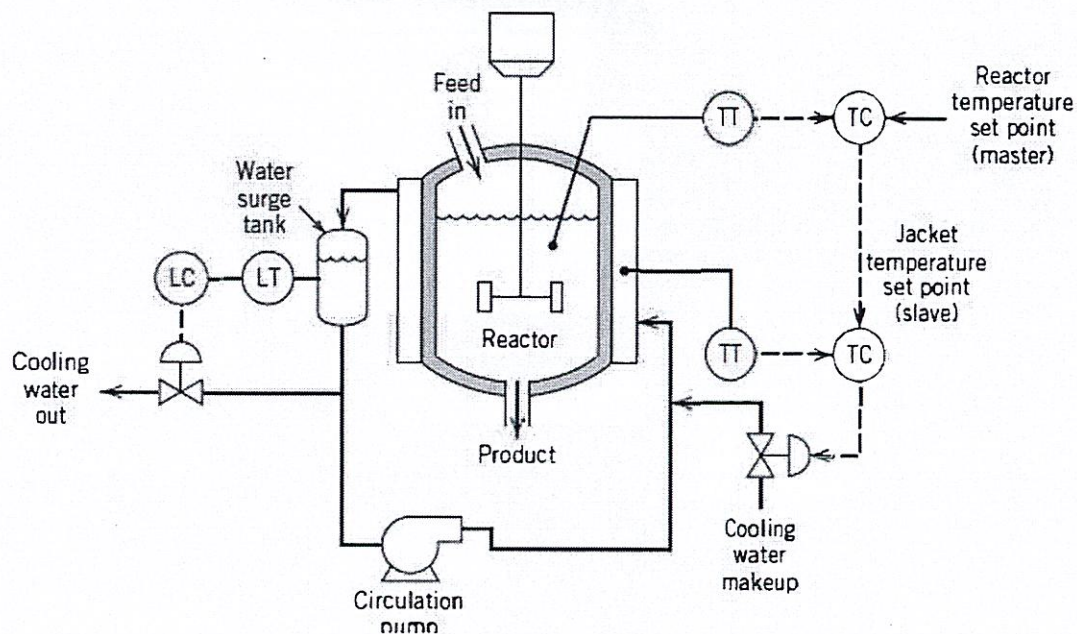


Figure 5: Cascade control of an exothermic chemical reactor

- (a) Sketch additional triple cascade controls by using same figure in the main question. (6 marks)

- (b) Draw a block diagram of the triple cascade control system, and discuss how this might provide an improved closed-loop response to a disturbance in cooling water flow rate

(14 marks)

END OF EXAMINATION PAPER

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APPENDIXES

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Table Laplace Transforms for Various Time-Domain Functions*

$f(t)$	$F(s)$
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. $\frac{1}{b_1 - b_2} (e^{-b_2 t} - e^{-b_1 t})$	$\frac{1}{(s+b_1)(s+b_2)}$
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. $\frac{b_3 - b_1}{b_2 - b_1} e^{-b_1 t} + \frac{b_3 - b_2}{b_1 - b_2} e^{-b_2 t}$	$\frac{s + b_3}{(s+b_1)(s+b_2)}$
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. $e^{-bt} \sin \omega t$	$\left. \begin{array}{l} \\ \end{array} \right\} b, \omega \text{ real}$ $\frac{\omega}{(s+b)^2 + \omega^2}$
18. $e^{-bt} \cos \omega t$	
19. $\frac{1}{\tau \sqrt{1-\zeta^2}} e^{-\zeta t/\tau} \sin(\sqrt{1-\zeta^2} t/\tau)$ ($0 \leq \zeta < 1$)	$\frac{s+b}{(s+b)^2 + \omega^2}$ $\frac{1}{\tau^2 s^2 + 2\zeta \tau s + 1}$
20. $1 + \frac{1}{\tau_2 - \tau_1} (\tau_1 e^{-t/\tau_1} - \tau_2 e^{-t/\tau_2})$ ($\tau_1 \neq \tau_2$)	$\frac{1}{s(\tau_1 s + 1)(\tau_2 s + 1)}$
21. $1 - \frac{1}{\sqrt{1-\zeta^2}} e^{-\zeta t/\tau} \sin[\sqrt{1-\zeta^2} t/\tau + \psi]$ $\psi = \tan^{-1} \frac{\sqrt{1-\zeta^2}}{\zeta}$, ($0 \leq \zeta < 1$)	$\frac{1}{s(\tau^2 s^2 + 2\zeta \tau s + 1)}$

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Table (Continued)

$f(t)$	$F(s)$
22. $1 - e^{-\zeta t/\tau} \left[\cos(\sqrt{1-\zeta^2}t/\tau) + \frac{\zeta}{\sqrt{1-\zeta^2}} \sin(\sqrt{1-\zeta^2}t/\tau) \right]$ ($0 \leq \zeta < 1$)	$\frac{1}{s(\tau^2 s^2 + 2\zeta\tau s + 1)}$
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. $\frac{d^n f}{dt^n}$	$s^n F(s) - s^{n-1}f(0) - s^{n-2}f^{(1)}(0) - \dots - sf^{(n-2)}(0) - f^{(n-1)}(0)$
26. $f(t - \theta)S(t - \theta)$	$e^{-\theta s}F(s)$
27. $\int_0^t f(\tau)d\tau$	$\frac{1}{s}F(s)$

Conservation of Mass

$$\left\{ \begin{array}{l} \text{rate of mass} \\ \text{accumulation} \end{array} \right\} = \left\{ \begin{array}{l} \text{rate of} \\ \text{mass in} \end{array} \right\} - \left\{ \begin{array}{l} \text{rate of} \\ \text{mass out} \end{array} \right\}$$

Conservation of Component i

$$\left\{ \begin{array}{l} \text{rate of component } i \\ \text{accumulation} \end{array} \right\} = \left\{ \begin{array}{l} \text{rate of component } i \\ \text{in} \end{array} \right\} - \left\{ \begin{array}{l} \text{rate of component } i \\ \text{out} \end{array} \right\} + \left\{ \begin{array}{l} \text{rate of component } i \\ \text{produced} \end{array} \right\}$$

DEGREE OF FREEDOM

$$NF = NV - NE$$

NV= NUMBER OF VARIABLES

NE= NUMBER OF EQUATION

NF= DEGREE OF FREEDOM

Step Input

$$u_S(t) = \begin{cases} 0 & t < 0 \\ M & t \geq 0 \end{cases} \rightarrow u_S(s) = \frac{M}{s}$$

Step input response

$$Y(s) = \frac{KM}{s(\tau s + 1)}$$

Conservation of Energy

$$\left\{ \begin{array}{l} \text{rate of energy} \\ \text{accumulation} \end{array} \right\} = \left\{ \begin{array}{l} \text{rate of energy in} \\ \text{by convection} \end{array} \right\} - \left\{ \begin{array}{l} \text{rate of energy out} \\ \text{by convection} \end{array} \right\} + \left\{ \begin{array}{l} \text{net rate of heat addition} \\ \text{to the system from} \\ \text{the surroundings} \end{array} \right\} + \left\{ \begin{array}{l} \text{net rate of work} \\ \text{performed on the system} \\ \text{by the surroundings} \end{array} \right\}$$

For any transfer function,

$$\frac{Y(s)}{U(s)} = G(s) \rightarrow Y(s) = \frac{K}{\tau s + 1} U(s)$$

the output response $y(t)$ can be determined for any input change $u(t)$ that has a Laplace transform.

Ramp Input

$$u_R(t) = \begin{cases} 0 & t < 0 \\ at & t \geq 0 \end{cases}$$

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Key Characteristics of Commercial PID Controllers

Controller Feature	Controller Parameter	Symbol	Units	Typical Range*
Proportional mode	Controller gain	K_c	Dimensionless [%/%, mA/mA]	0.1–100
	Proportional band	$PB = 100\%/K_c$	%	1–1000%
Integral mode	Integral time (or reset time)	τ_I	Time [min, s]	0.02–20 min 1–1000 s
	Reset rate	$1/\tau_I$	Repeats/time [min ⁻¹ , s ⁻¹]	0.001–1 repeats/s 0.06–60 repeats/min
	Integral mode “gain”	K_I	Time ⁻¹ [min ⁻¹ , s ⁻¹]	0.1–100
Derivative mode	Derivative time	τ_D	Time [min, s]	0.1–10 min 5–500 s
	Derivative mode “gain”	K_D	Time [min, s]	0.1–100
	Derivative filter parameter	α	Dimensionless	0.05–0.2
Control interval (Digital controllers)		Δt	Time [s, min]	0.1 s–10 min

*Based on McMillan (2015).

$$G(s) = \frac{Y(s)}{U(s)} = \frac{K_1 K_2}{(\tau_1 s + 1)(\tau_2 s + 1)} = \frac{K}{(\tau_1 s + 1)(\tau_2 s + 1)}$$

Damping Coefficient	Characterization of Response	Roots of Characteristic Equation*
$\zeta > 1$	Overdamped	Real and unequal
$\zeta = 1$	Critically damped	Real and equal
$0 < \zeta < 1$	Underdamped	Complex conjugates (of the form $a + jb$ and $a - jb$)

2nd order system

$$Y(s) = \frac{N(s)}{D(s)} = \frac{N(s)}{\prod_{i=1}^n (s + b_i)} = \sum_{i=1}^n \frac{\alpha_i}{s + b_i} \quad \text{- Partial Fraction Expansion}$$

$$f(y, u) \cong f(\bar{y}, \bar{u}) + \left. \frac{\partial f}{\partial y} \right|_{\bar{y}, \bar{u}} (y - \bar{y}) + \left. \frac{\partial f}{\partial u} \right|_{\bar{y}, \bar{u}} (u - \bar{u}) \quad \text{- Taylor series Expansion}$$

