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UNIVERSITY COLLEGE TATI

UNIVERSITY COLLEGE TATI (UC TATI)

FINAL EXAMINATION QUESTION BOOKLET

COURSE CODE	: BCE 3234
COURSE	: PROCESS CONTROL
SEMESTER/SESSION	: 2-2024/2025
DURATION	: 3 HOURS

Instructions:

1. This booklet contains 4 questions. Answer **ALL** questions.
2. All answers should be written in answer booklet.
3. Write legibly and draw sketches wherever required.
4. If in doubt, raise your hands and ask the invigilator.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO
YOU ARE ALLOWED TO BRING TWO (2) A4 PAPER

THIS BOOKLET CONTAINS 7 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

a)

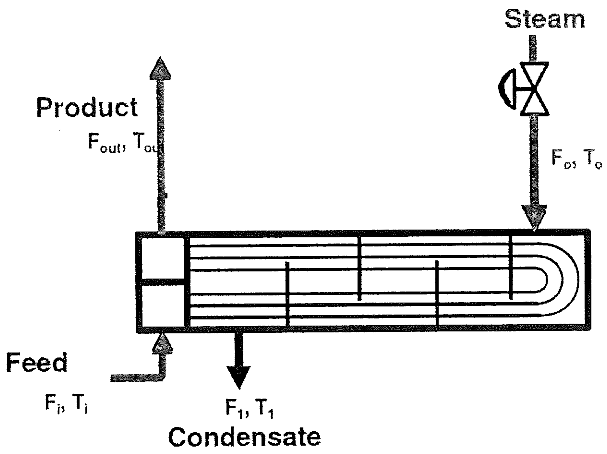


Figure 1

Figure 1 shows the heat exchanger system. This system require control system to maintain the temperature.

i) Illustrate how the feedback control system is operated in Figure 1. Re-draw Figure 1. (4 marks)

ii) Analyse: (5 marks)

   a) Controlled variable
   b) Measuring instrument
   c) Manipulated variable
   d) Final control element
   e) Disturbance

iii) Illustrate the feedback control loop for this process. (6 marks)

b) To bake cookies, an electric oven needs to be preheated to 180°C. After setting this desired temperature, a sensor measures the current temperature inside the oven. If the oven's temperature is below the set point, a signal is sent to the heater to turn on until the oven reaches the target temperature.

i) In this scenario, diagnose:

a) Control objective

b) Control variable

c) How the error of this system is calculated

ii) Illustrate the classical control loop for this system.

(10 marks)

QUESTION 2

a)

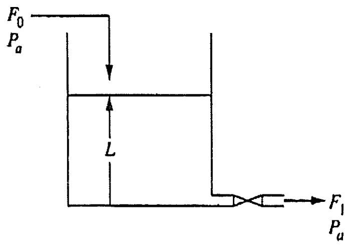


Figure 2

In Figure 2, the flow out depends on the level in the tank through a nonlinear relationship, and after linearization, the level model is:

$$\tau \frac{dL'}{dt} + L' = K_p F_0'$$

Given:

Cross-section area A = 7 m^2, initial flows in and out, = 100 m^3/min, initial level (L_s) = 7 m, k_{F1} = 37.8 (m^3/h)/(m^{-5}).

$$\tau = A/(0.5 k_{F1} L_s^{-0.5})$$

$$K_p = 1/(0.5 k_{F1} L_s^{-0.5})$$

i) Find the Laplace Transform for the above equation (3 marks)

ii) Calculate K_p and τ (4 marks)

iii) Determine the transfer function G(s) for this system (3 marks)

iv) If the flow inlet is changed to 110 m^3/min. Find the equation for dynamic response, L(t). (4 marks)

v) Determine the level achieve in 5 hours. (4 marks)

b) A stirred tank blending system initially is full of water and is being fed pure water at a constant flowrate, q. At a particular time, an operator shuts off the pure water flow and add caustic solution at the same volumetric flowrate, q but with concentration, c. Given V = 2 m^3, q = 0.4 m^3/min and c_i = 50 kg/min. If the liquid volume is constant, the dynamic model for this process is:

$$V\frac{dc}{dt} + qc = qc_i \quad \text{where} \quad c(0) = 0$$

Find the concentration response of the reactor effluent stream, *c(t).*

(7 marks)

QUESTION 3

Figure 3 shows a series configuration of two noninteracting tanks where any changes in the liquid level of Tank 1 will take 3 minutes to impact the liquid level in Tank 2. Disregard valves R_1 and R_2.

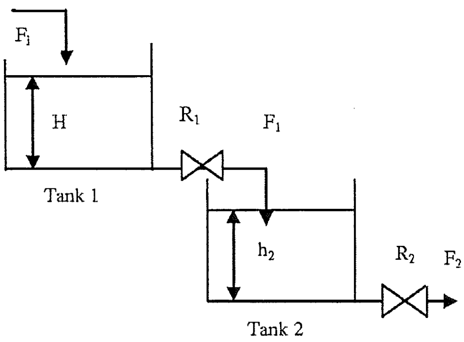


Figure 3

Given: k_{p1} = 3 min/m^2, k_{p2} = 1.5 min/m^2, τ_{p1} = 10 min, τ_{p2} = 20 min, F_1 = 50 m^3/min

$$\frac{h_1(s)}{F_1(s)} = \frac{k_{p1}}{\tau_{p1s} + 1}$$

$$\frac{h_2(s)}{h_1(s)} = \frac{k_{p2}e^{-tds}}{\tau_{p2s} + 1}$$

a) Solve the transfer function for $\frac{h_2(s)}{F_1(s)}$

b) If the operator suddenly increases the inlet flowrate, F_1 to 55 m^3/min, find the height response for Tank 2, h_2 (t).

c) Determine the time for h_2 (t) to achieve in 10.5 m. Show all methods.

(25 marks)

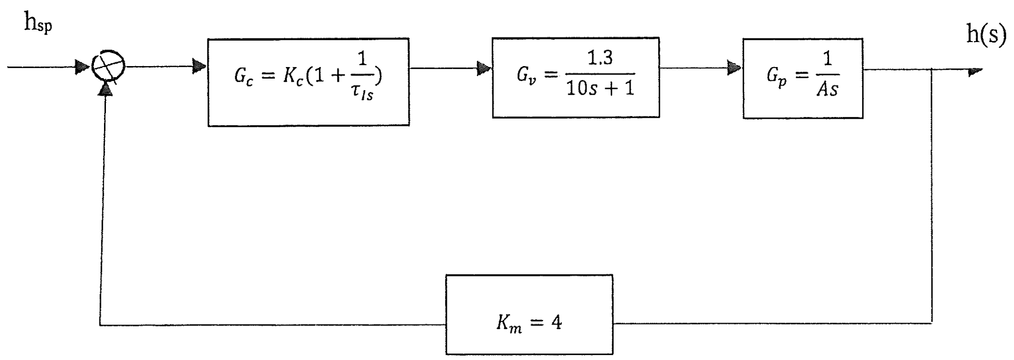
QUESTION 4

a) Find the values of the controller gain, kc that make the feedback control system stable using Routh-Hurwitz criterion. Given the characteristics equation:

$$10s^3 + 17s^2 + 8s + 1 + kc = 0$$

(10 marks)

b) Determine the range of Kc and τ_1 to form a stable system using RH method. Given A = 3 ft^2



(15 marks)

---End of question---

ATTACHMENTS

Table 1: Laplace transform for various time domain function

$f(t)$	$F(s)$
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. $\cos \omega t$	$\dfrac{s}{s^2 + \omega^2}$
16. $\sin(\omega t + \phi)$	$\dfrac{\omega \cos \phi + s \sin \phi}{s^2 + \omega^2}$
17. $e^{-bt} \sin \omega t$ b, ω real	$\dfrac{\omega}{(s + b)^2 + \omega^2}$
18. $e^{-bt} \cos \omega t$ b, ω real	$\dfrac{s + b}{(s + b)^2 + \omega^2}$
19. $\dfrac{1}{\tau\sqrt{1 - \zeta^2}} e^{-\zeta t/\tau} \sin(\sqrt{1 - \zeta^2}\, t/\tau)$ $(0 \le \lvert\zeta\rvert < 1)$	$\dfrac{1}{\tau^2 s^2 + 2\zeta\tau s + 1}$
20. $1 + \dfrac{1}{\tau_2 - \tau_1}(\tau_1 e^{-t/\tau_1} - \tau_2 e^{-t/\tau_2})$ $(\tau_1 \ne \tau_2)$	$\dfrac{1}{s(\tau_1 s + 1)(\tau_2 s + 1)}$
21. $1 - \dfrac{1}{\sqrt{1 - \zeta^2}} e^{-\zeta t/\tau} \sin[\sqrt{1 - \zeta^2}\, t/\tau + \psi]$ $\psi = \tan^{-1}\dfrac{\sqrt{1 - \zeta^2}}{\zeta}, \ (0 \le \lvert\zeta\rvert < 1)$	$\dfrac{1}{s(\tau^2 s^2 + 2\zeta\tau s + 1)}$
22. $1 - e^{-\zeta t/\tau}[\cos(\sqrt{1 - \zeta^2}\, t/\tau) + \dfrac{\zeta}{\sqrt{1 - \zeta^2}} \sin(\sqrt{1 - \zeta^2}\, t/\tau)]$ $(0 \le \lvert\zeta\rvert < 1)$	$\dfrac{1}{s(\tau^2 s^2 + 2\zeta\tau s + 1)}$
23. $1 + \dfrac{\tau_3 - \tau_1}{\tau_1 - \tau_2} e^{-t/\tau_1} + \dfrac{\tau_3 - \tau_2}{\tau_2 - \tau_1} e^{-t/\tau_2}$ $(\tau_1 \ne \tau_2)$	$\dfrac{\tau_3 s + 1}{s(\tau_1 s + 1)(\tau_2 s + 1)}$
24. $\dfrac{df}{dt}$	$sF(s) - f(0)$
25. $\dfrac{d^n f}{dt^n}$	$s^n F(s) - s^{n-1} f(0) - s^{n-2} f^{(1)}(0) - \cdots - s f^{(n-2)}(0) - f^{(n-1)}(0)$
26. $f(t - t_0) S(t - t_0)$	$e^{-t_0 s} F(s)$

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

Characteristic equation:

$$1 + G_C G_V G_P G_M = 0$$