PP1

TECHNICAL UNIVERSITY OF MOMBASA

School of Engineering and Technology

Department of Electrical and Electronic Engineering

UNIVERSITY EXAMINATION FOR:

Bachelor of Technology in Electrical Engineering

TEE 4318: PROCESS CONTROL SYSTEMS

END OF SEMESTER EXAMINATION

SERIES: APRIL 2025 EXAM

TIME: 2 HOURS

DATE: April 2025

Instructions to Candidates

You should have the following for this examination

-Answer Booklet, examination pass and student ID

This paper consists of **five** Questions. Attempt any **THREE** Questions.

Do not write on the question paper.

Question ONE

(a) Draw a (general) block diagram of a feedback process control system and describe the function (purpose) of each of the blocks and signals in your block diagram. (5 marks)

(b) Distinguish between supervisory control and direct digital control as applied in digital process control systems hence draw process control loops for systems employing:

i) Computer Supervisory control

ii) Direct digital control (DDC)

(8 marks)

(c) State any two practical applications of on-off controllers

(d) Explain the term proportional band as applied to proportional controllers (2 marks)

(e) A proportional control system for angular motion of a shaft consists of a D.C. motor with transfer function: $1/[s(s+4)]$ and a negative feedback loop with a measurement system having a transfer function of 0.1. Determine the value of the proportional gain constant which will give a critically damped system. (5 marks)

Question TWO

(a) A liquid-level control system linearly converts a displacement of 2 to 3 m into a 4- to 20-mA control signal. A relay serves as the two-position controller to open or close an inlet valve. The relay closes at 12 mA and opens at 10 mA. Determine:

i) The relation between displacement level and current,

ii) The neutral zone or displacement gap in meters.

(6 marks)

(b) State the advantages and disadvantages of applying PID controllers for a process control loop (4 marks)

(c) A three-term controller is described by the equation

$$\theta_c(t)=20[e(t)+\frac{1}{T_r}\int_0^t e(t)dt+T_d\frac{de(t)}{dt}]$$

Where, θ_c is controller output, T_r is the integral reset time., $e(t)$ is system error and T_d is the derivative time. This controller is used to control a process with transfer function

$$G(s)=\frac{40}{10s^2+80s+800}$$

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Unity feedback is used. If the integral action is not employed, find the derivative time required to make the closed loop damping ratio unity. (10 marks)

Question THREE

(a) Distinguish between the following:
   i) Lumped and Distributed parameter models
   ii) Interacting and non-interacting systems
   iii) Self-regulation and regulatory control operation
   iv) Continuous processes and Batch processes

(8 marks)

(b) Determine a model for the temperature of a room of Figure Q 3(b) containing a heater which supplies heat at the rate q_1 and the room loses heat at the rate q_2. *R* is the thermal resistance of the walls. And the combined thermal capacity is *C* (6 marks)

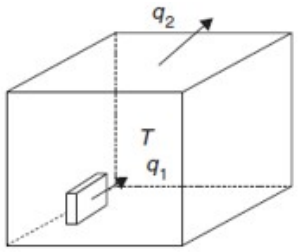

Figure Q 3(b)

(c) Describe the three parts of final control element operation. (4 marks)
(d) Explain the process of control valve size determination (valve sizing). (2 marks)

Question FOUR

(a) Explain what is meant by controller tuning (2 marks)
(b) Briefly explain the ultimate cycle method of PID controller tuning. (5 marks)
(c) A transient disturbance test is run on a process loop. The results of a 9 % controlling variable change give a process-reaction graph is shown in Figure Q 4(c). Find settings for the constants Kp, Ki and Kd of the PID controller action. (6 marks)

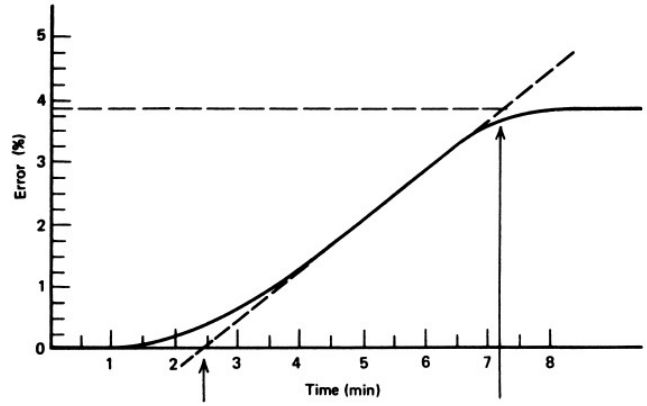

Figure Q4 (c)

(d) With the aid of response characteristics, explain the following criteria as used for the evaluation of a process loop responses.

i) Quarter amplitude response
ii) Minimum area response

(5 marks)

(e) A stepper motor has 10° per step and must rotate at 250 rpm. Determine the required input pulse rate, in pulses per second. (2 marks)

Question FIVE

(a) Figure Q5 (a) shows a two-variable control system.

i) State the type of control scheme used
ii) Explain the operation of the system
iii) Draw a block diagram representation for the system

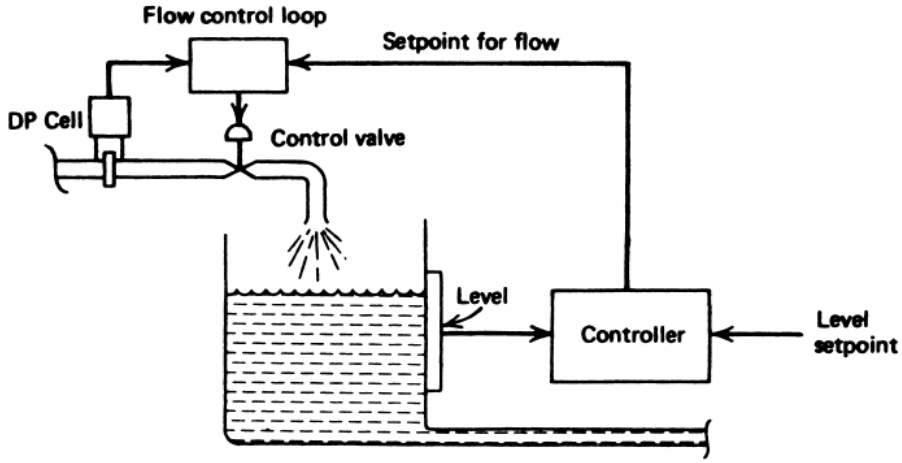

Figure Q5 (a) (8 marks)

(b) Differentiate inherent characteristics and installed characteristics of a control valve. (2 marks)

(c) Compare linear valve, Quick opening valve and equal percentage valve characteristics (3 marks)

(d) An equal percentage valve has a maximum flow of 50 cm^3/s and a minimum of 2 cm^3/s. If the full travel is 3 cm, find the flow at a 1- cm opening. (3 marks)

(e) With the aid of a sketch explain the operation of a pneumatic relay as an amplifier (4 marks)

Type of Controller	Loop Tuning Constant	Tuning Equation
Proportional (P)	K_P	$K_P = \frac{\Delta CV}{(L_t)(N)}$
Proportional-Integral (PI)	K_P	$K_P = \frac{(0.9)(\Delta CV)}{(L_t)(N)}$
	T_I	$T_I = (3.33)(L_t)$
Proportional-Integral-Derivative (PID)	K_P	$K_P = \frac{(1.2)(\Delta CV)}{(L_t)(N)}$
	T_I	$T_I = (2)(L_t)$
	T_D	$T_D = (0.5)(L_t)$

Ziegler-Nichols open-loop tuning equations.