2601/201
2602/201
2603/201
CONTROL SYSTEMS AND PROGRAMMABLE LOGIC CONTROLLERS
June/ July 2019
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING
(POWER OPTION)
(TELECOMMUNICATION OPTION)
(INSTRUMENTATION OPTION)
MODULE II

CONTROL SYSTEMS AND PROGRAMMABLE LOGIC CONTROLLERS

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:

Answer booklet;
Mathematical tables/Non-programmable Scientific calculator;
Drawing instrumens;
Table of Laplace Transforms.

*This paper consists of **EIGHT** questions in **TWO** sections; **A** and **B**.*
*Answer **THREE** questions from section **A** and **TWO** questions from section **B** in the answer booklet provided.*
All questions carry equal marks.
Maximum marks for each part of a question are as indicated.
Candidates should answer the questions in English.

This paper consists of 9 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

Turn over

SECTION A: CONTROL SYSTEMS

*Answer **THREE** questions from this section.*

1. (a) For each of the following control systems, state with a reason whether it is open or closed loop:

(i) a bread toaster;
(ii) a man walking on a road;
(iii) a photocell-controlled street lighting system.

(6 marks)

(b) (i) State the **three** types of forces that exist in translational control systems.

(ii) Figure 1 shows a mass spring system.

(I) Derive the system equation if at equilibrium condition M = 15 kg, B = 40 N/M/sec and K = 10 N/M.

(II) Derive the transfer function using Laplace transforms. (9 marks)

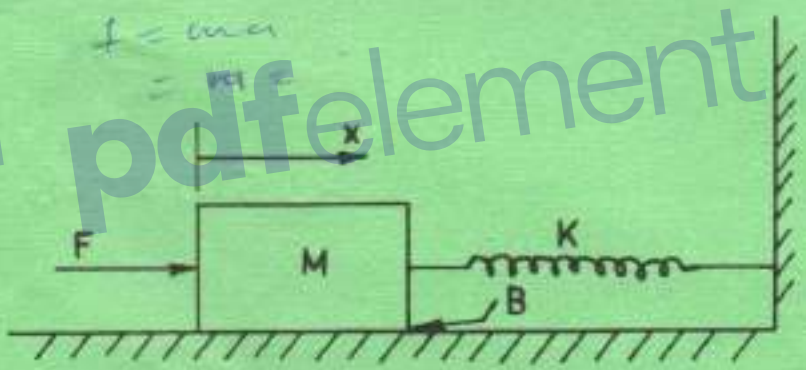

Fig.1

(c) (i) With aid of a sketch, define an impulse function.

(ii) Determine the transfer function of a system whose time response is $f(t)=e^{-t}$.
(5 marks)

2. (a) (i) State **two** reasons why mechanical system are usually studied using electrical analogy.

(ii) Figure 2 shows a circuit diagram of an Op-amp based electrical network.

Assuming the Op-amp is ideal, determine its transfer function, $V_{o(s)}/V_{in(s)}$.

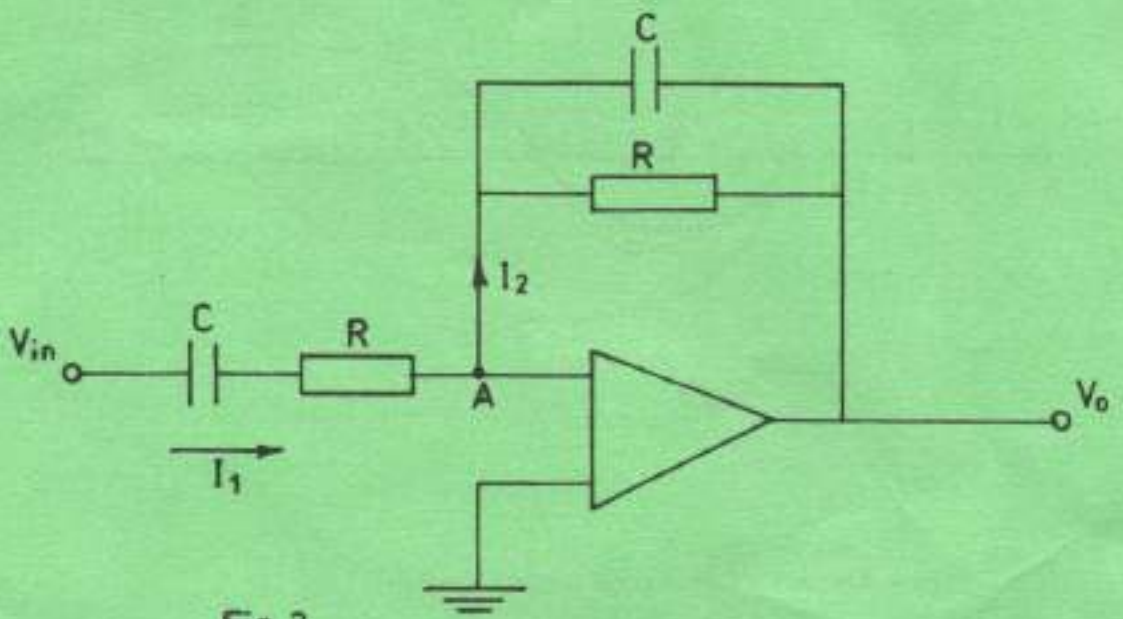

Fig. 2

(8 marks)

(b) A control system has poles at $S_1 = -1$ and $S_2 = -2 \pm j$, zeros at $S_3 = -3 \pm j$. If the gain factor is 5:

(i) Draw the pole-zero plot;

(ii) Write down the transfer function of the system;

(iii) State with a reason whether the system is stable or not.

(6 marks)

(c) A feedback control system has a characteristic equation given by:

$S(S^2 + S + 1)(S + 4) + K = 0$

Using the Routh-Hurwitz stability analysis method, determine the range of K for the system to remain stable.

(6 marks)

3. (a) (i) State **two** properties of signal flow graphs.

(ii) Figure 3 shows a signal flow graph of a control system. Obtain its transfer function.

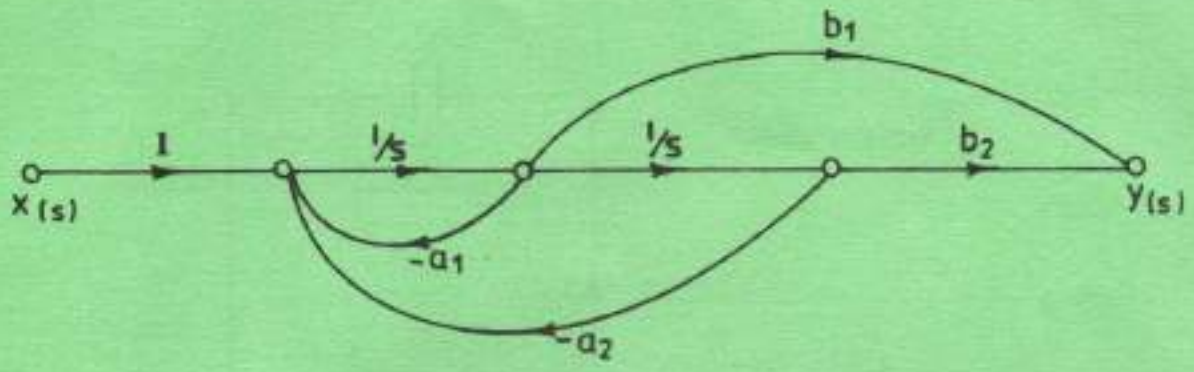

Fig.3

(10 marks)

(b) Figure 4 shows a liquid level control system. Take:

q_i = inflow rate of the liquid in m^3/sec
q_o = outflow rate of the liquid in m^3/sec
h = height of the liquid in m
R = resistance of the outlet pipe
C = capacitance of the tank

Derive the expression for:
(i) outflow, q_o
(ii) rate of storage;
(iii) overall transfer function of the system.

(6 marks)

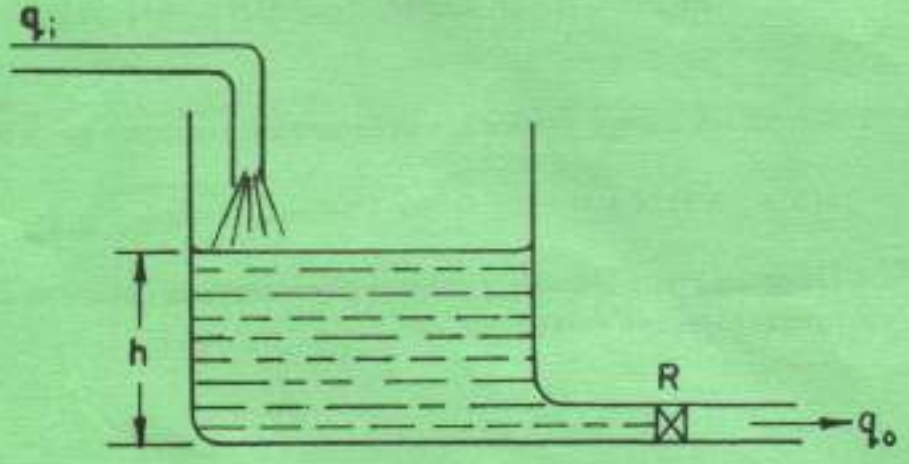

Fig. 4

(c) Explain the importance of each of the following with respect to analog computing:

(i) time scaling;
(ii) amplitude scaling. (4 marks)

4 (a) State:

(i) **two** types of stepper motors;
(ii) **two** advantages of D.C tachometers. (4 marks)

(b) A servomeechanism is represented by the equation:

$$\frac{d^2\theta}{dt^2} + 10\frac{d\theta}{dt} = 150\,E$$

Where $E = (r - \theta)$ is the actuating signal.

Determine the:

(i) transfer function;
(ii) undamped frequency of oscillations;
(iii) damping ratio;
(iv) damped frequency of oscillations. (9 marks)

(c) (i) Define steady-state error.

(ii) The open loop transfer function of a control system is given by:

$$G(s) = \frac{4}{s+1}$$

(I) State with reasons whether the system is a type 0, 1 or 2.

(II) Determine steady-state error when a unit step input is applied. (7 marks)

5 (a) (i) State the Nyquist stability criterion.

(ii) A system's open-loop transfer function is given by:

$$G_{(s)}H_{(s)} = \frac{1}{s(1+2s)(1+s)}$$

(I) Show that the phase cross over frequency, $w = \frac{1}{\sqrt{2}}$ rad/sec.

(II) Determine the phase cross over magnitude.

(iii) Comment on the stability of the system in a (ii). (12 marks)

(b) Figure 5 shows an asymptotic Bode plot of a control system. Determine its transfer function.

(8 marks)

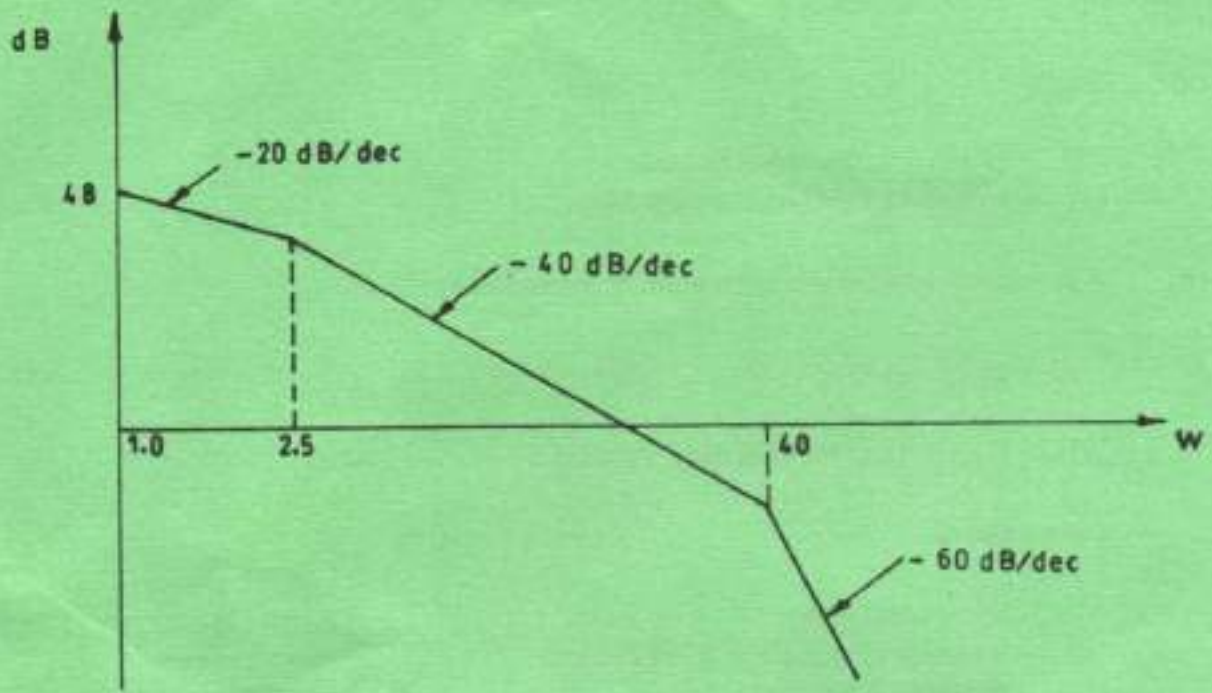

Fig. 5

SECTION B: PROGRAMMABLE LOGIC CONTROLLERS

*Answer **TWO** questions from this section.*

6 (a) Describe each of the following sensors as used in programmable logic controllers (PLC):

(i) optical;
(ii) ultrasonic. (4 marks)

(b) (i) A motor, M is controlled to run in forward and reverse directions by two buttons F and R respectively. The motor should not run when both buttons are pressed.

(I) Draw the ladder diagram for this control;

(II) Write the equivalent instruction list program for the ladder diagram.

(ii) Figure 6 shows a ladder diagram of a control system. Describe the system operation.

(13 marks)

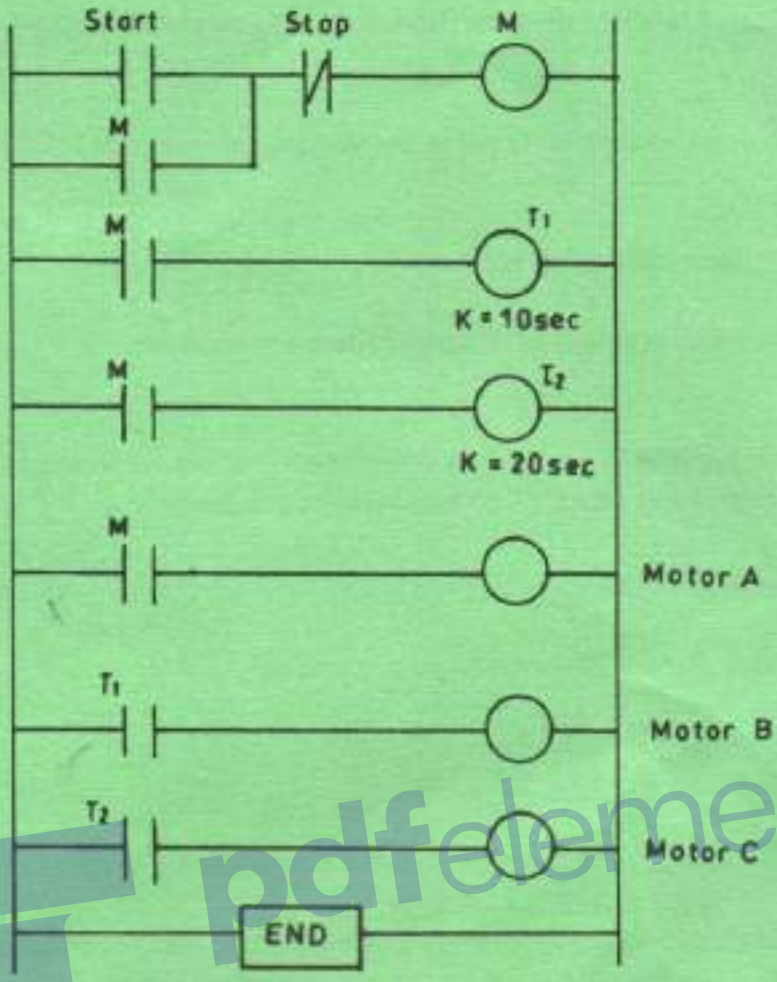

Fig. 6

(c) Define each of the following with respect to PLC memory:

(i) Address;
(ii) Random access;
(iii) Solid State Drive (SSD).

(3 marks)

7. (a) (i) Define a SCADA system stating **two** potential areas of application.

(ii) Describe each of the following SCADA system communication media:

(I) coaxial cable;
(II) satellite;
(III) fibre optic cable.

(9 marks)

(b) (i) SCADA software can be compromised either internally or externally. List **four** risks that the system could suffer after such attacks.

(ii) Draw a labelled diagram illustrating a SCADA network "ring of defences".

(9 marks)

(c) State **two** organisations involved in the standardization of SCADA systems.

(2 marks)

8. (a) (i) Define a calibration software.

(ii) Explain **three** merits of using calibration software.

(7 marks)

(b) With the aid of labelled diagrams, describe each of the following Highway Addressable Remote Transducer (HART) communication modes:

(i) point-to-point;

(ii) mutli-drop.

(8 marks)

(c) State:

(i) **two** functions of Network Adaptor Cards (NAC) in data networks;

(ii) **three** parameters that two NACs must agree on to communicate.

(5 marks)

TABLE OF LAPLACE TRANSFORMS

	FUNCTION F(t)	TRANSFORM $\int_0^\infty e^{-st} F(t)\,dt$
1.	1	$1/s$
2.	e^{at}	$1/(s - a)$
3.	sin at	$a/(s^2 + a^2)$
4.	cos at	$s/(s^2 + a^2)$
5.	t	$1/s^2$
6.	t^n (n a +ve integer)	$n!/s^{n+1}$
7.	sinh at	$a/(s^2 - a^2)$
8.	cosh at	$s/s^2 - a^2)$
9.	t sin at	$2as/(s^2 + a^2)^2$
10.	t cos at	$(s^2 - a^2)/(s^2 + a^2)^2$
11.	$e^{-at}t^n$	$n!/(s + a)^{n+1}$
12.	e^{-at} cos ωt	$(s + a)/[(s + a)^2 + \omega^2]$
13.	e^{-at} sin ωt	$\omega/[(s + a)^2 + \omega^2]$
14.	e^{-at} cosh ωt	$(s + a)/[(s + a)^2 - \omega^2]$
15.	e^{-at} sinhωt	$\omega/[(s + a)^2 - \omega^2]$

Some Theorems used in Laplace Transforms.

1. If f(s) = L{F(t)}, then f(s + a) = L{e^{-at} F(t)}
2. L{dx/dt} = sL{x} - x(0) (b) L{d^2x/dt^2} = s^2L{x} -sx(0) - x'(0)

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