2601/201
2602/201
2603/201
CONTROL SYSTEMS AND
PROGRAMMABLE LOGIC CONTROLLERS
June/July 2021
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ELECTRICAL AND ELECTRONICS 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;*
- *Drawing instruments;*
- *Non-programmable scientific calculator;*
- *Polar curve.*

*This paper consists of **EIGHT** questions in **TWO** sections, **A** and **B** in the answer booklet provided.*
*Answer any **THREE** questions from section **A**, and any **TWO** questions from section **B**.*
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 8 printed pages and one insert.

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 any **THREE** questions from this section.*

1. (a) Define each of the following with respect to control systems:

(i) controlled variable;
(ii) manipulated variable.

(2 marks)

(b) (i) State **three** merits of a closed loop control system.
(ii) With the aid of a labelled block diagram, describe an open loop control system.

(9 marks)

(c) Figure 1 shows a block diagram of a control system. Using block diagram reduction techniques, determine its transfer function. (9 marks)

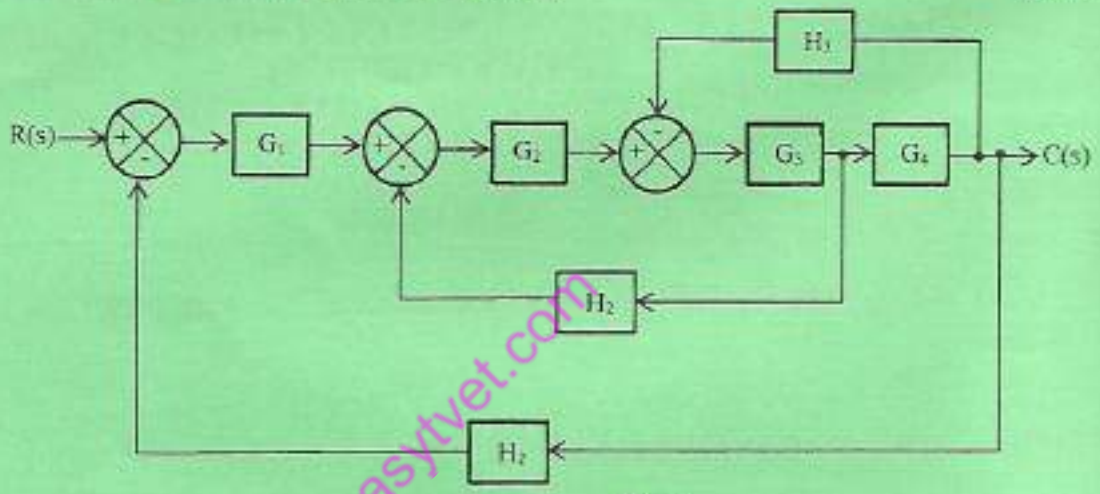

Fig. 1

2. (a) State **two** advantages of a d.c servo-motors over a.c servo motors. (2 marks)

(b) With the aid of a labelled block diagram, describe the working principle of a d.c servo-motor. (7 marks)

(c) Figure 2 shows an armature controlled d.c motor. Show that its transfer function is given by the expression:

$$\frac{\theta_{(s)}}{E_{a(s)}} = \frac{K}{s\left[L_a J s^2 + (L_{af} + R_a J)s + R_a f + K_{tb}\right]}$$

(11 marks)

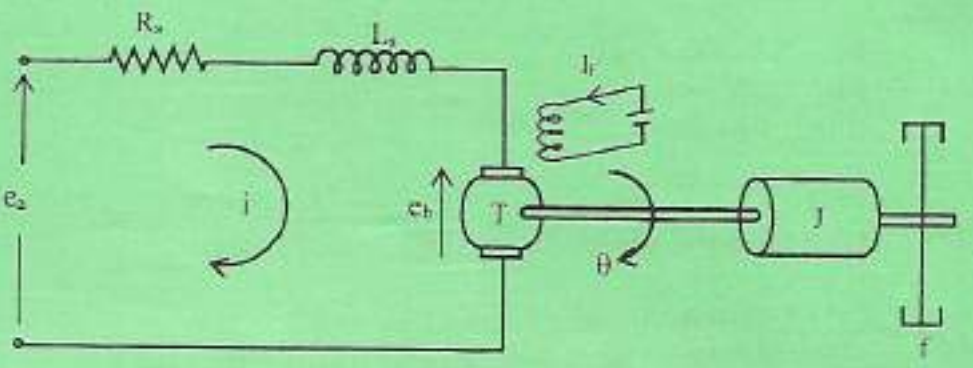

Fig. 2

3. (a) Define each of the following input test signals used for analysis of control systems:

(i) step;
(ii) ramp;
(iii) constant acceleration.

(3 marks)

(b) A unity feedback system subjected to a unit step input has an open loop transfer function $G_{(s)} = \frac{K}{s(s+10)}$.

Determine the:

(i) characteristic equation;
(ii) gain K, so that the system will have a damping ratio of 0.5;
(iii) settling time;
(iv) percentage overshoot.

(13 marks)

(c) Figure 3 shows a three input summing amplifier. Derive the expression for the output voltage.

(4 marks)

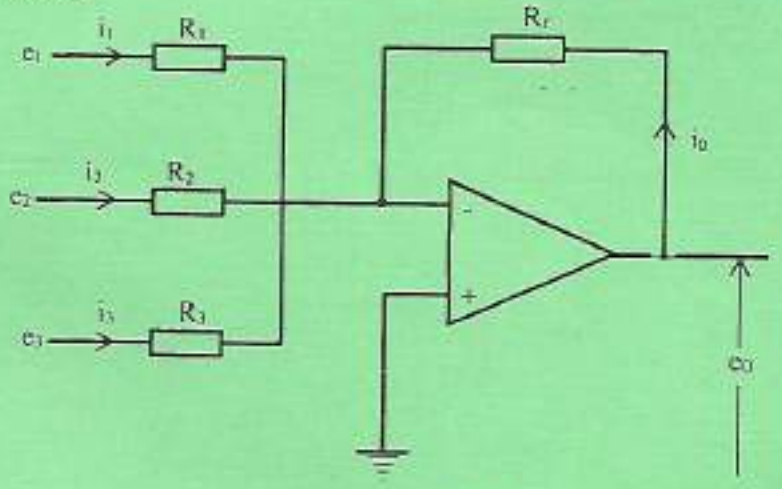

Fig. 3

4. (a) Define each of the following in relation to signal flow graphs:

(i) feedback path;
(ii) self loop;
(iii) path gain.

(3 marks)

(b) Figure 4 shows a block diagram of a control system.

(i) draw its equivalent signal flow graph;
(ii) determine the transfer function of the system using the signal flow graph in b (i).

(13 marks)

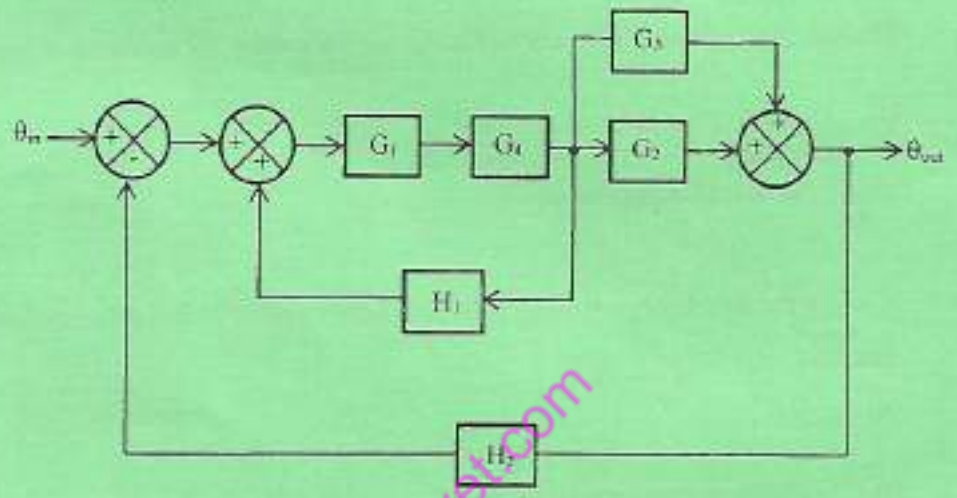

Fig. 4

(c) Figure 5 shows an R-C circuit diagram. Derive its transfer function. (4 marks)

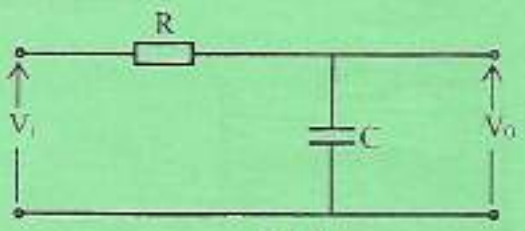

Fig. 5

5. (a) (i) (I) Define the term time scaling with respect to analogue computing.
(II) State **three** reasons for time scaling.

(ii) Draw an analogue computer diagram to solve the following simultaneous differential equations:

$$\dot{y} = x + 9$$
$$\dot{x} = y + 4$$

(10 marks)

(b) (i) State **two** demerits of stability analysis using Nyquist method.
(ii) Table 1 shows the open loop frequency response of a control system. Draw Nyquist diagram for the system and determine the:

(I) gain margin;
(II) phase margin;
(III) comment on stability of the system.

(10 marks)

Table 1

$\omega(rads/\sec)$	1	2	3	4	5
GH (dB)	4.5	1.6	0.8	0.5	0.3
Phase angle (θ°)	−127	−152	−168	−180	−188

SECTION B: PROGRAMMABLE LOGIC CONTROLLERS

*Answer any **TWO** questions from this section*

6. (a) List **two:**

(i) programming languages used in programmable logic controllers;
(ii) factors considered when selecting a programmable logic controllers (PLC) for a particular application.

(4 marks)

(b) Outline the essential checks while commissioning a programmable logic controller (PLC).

(6 marks)

(c) A staircase light is controlled by two switches 1 and 2. One switch is located at the top of the staircase and the other is at the bottom. The light can be switched on at the bottom and switched off at the top of the staircase and vice versa.

(i) draw the truth table for this system;
(ii) write the Boolean equation for the system control;
(iii) implement the circuit using NAND gates only;
(iv) draw a PLC ladder diagram to control the light.

(10 marks)

7. (a) (i) Figure 6 shows a logic diagram of a control system:

(I) write its Boolean expression;
(II) draw its ladder logic diagram;
(III) write its instruction list program.

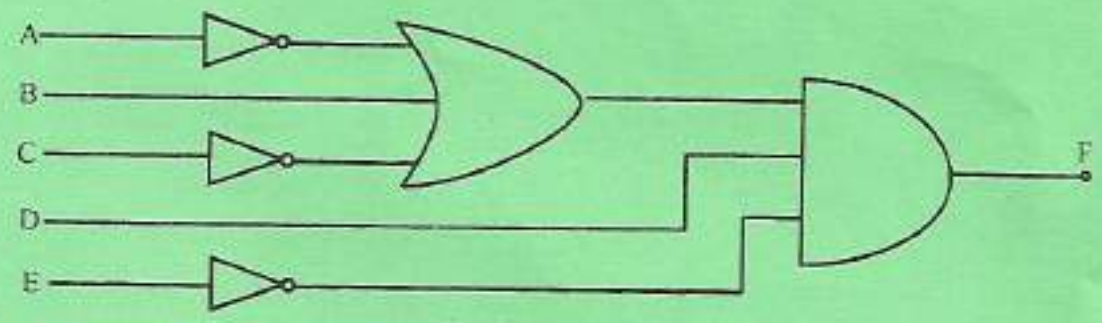

Fig. 6

(ii) State **two** reasons why PLCs are preferred over relay logics in sequential control. (10 marks)

(b) (i) State **two** wireless topologies used in networking.
(ii) With the aid of labelled block diagrams describe two wired network topologies. (10 marks)

8. (a) (i) Describe a SCADA system.
(ii) Explain the functions of each of the following SCADA components:

(I) remote telemetry units (RTUs);
(II) master unit;
(III) communication network.

(11 marks)

(b) Distinguish between supervisory control and direct digital control. (4 marks)

(c) A data logger sequentially samples 100 process parameters. It requires 15 instructions at 5 μs per instruction for the computer to address and process one line of data. The multiplexer switching time is 2.5 μs and the analog to digital converter (ADC) conversion time is 34 μs. Determine the maximum sampling rate for a particular line. (5 marks)

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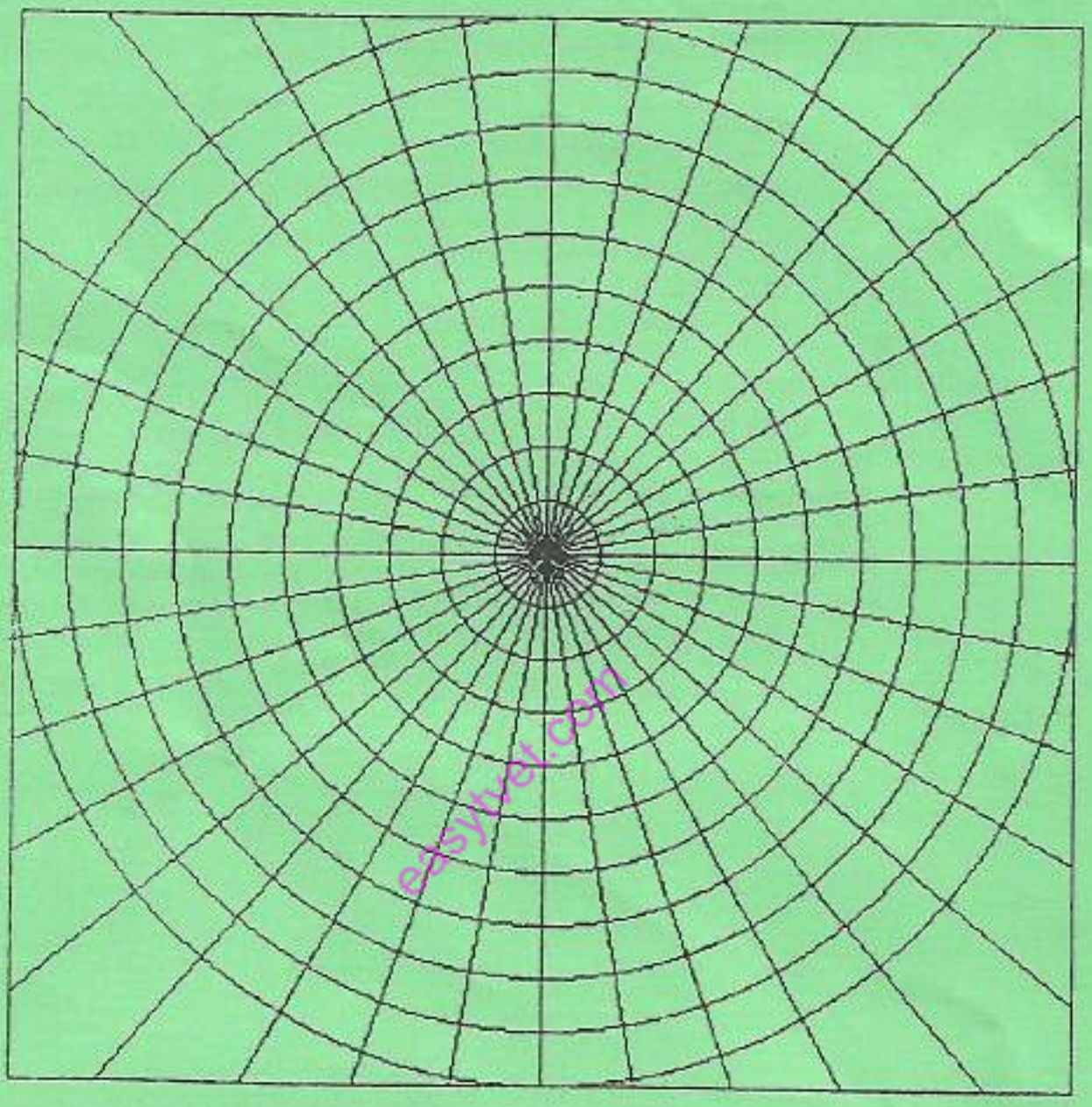

POLAR CURVE

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