2501/302   2508/302
2503/302   2509/302
CONTROL SYSTEMS AND INSTRUMENTATION
Oct./Nov. 2022
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN MECHANICAL ENGINEERING
(PRODUCTION OPTION)
(WELDING AND FABRICATION OPTION)
(CONSTRUCTION PLANT OPTION)
DIPLOMA IN AUTOMOTIVE ENGINEERING

MODULE III

CONTROL SYSTEMS AND INSTRUMENTATION

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Answer booklet;
Non-programmable Scientific calculator;
Drawing instruments.
This paper consists of EIGHT questions in TWO sections; A and B.
Answer FIVE questions by choosing at least TWO questions from each section 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 6 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 at least TWO questions from this section.

1. (a) Differentiate between each of the following with reference to control systems:
        (i)   man-made systems and natural systems;
        (ii) open-loop systems and hybrid systems.   (4 marks)

    (b) With the aid of a labelled block diagram, describe the elements of a feedback control system.   (8 marks)

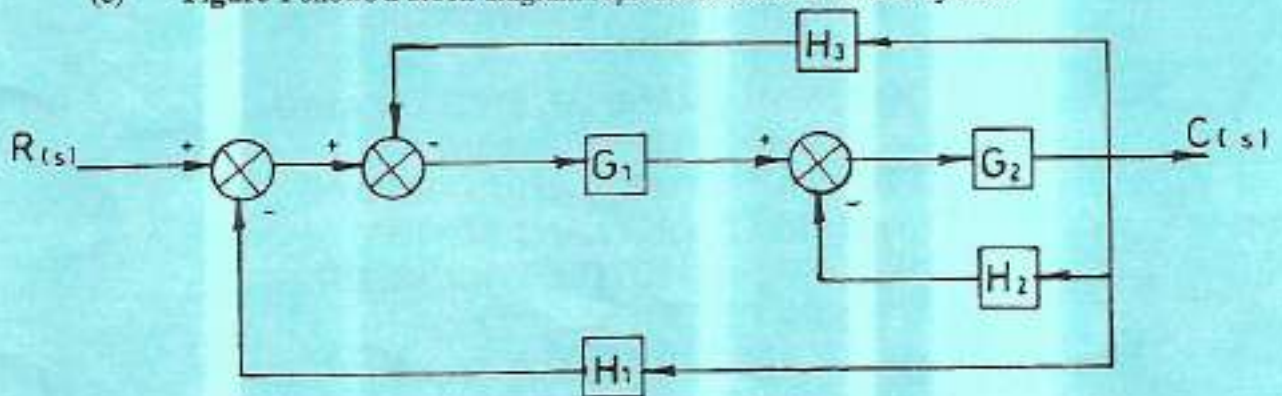   (c) **Figure 1** shows a block diagram representation of a control system.

Fig.1

Determine the:
(i)   equivalent canonical form;
(ii) closed-loop transfer function.   (8 marks)

2. (a) Write Mason's gain formula with respect to signal flow graph.   (2 marks)

    (b) **Figure 2** shows a signal flow graph of a control system. Determine the system gain.
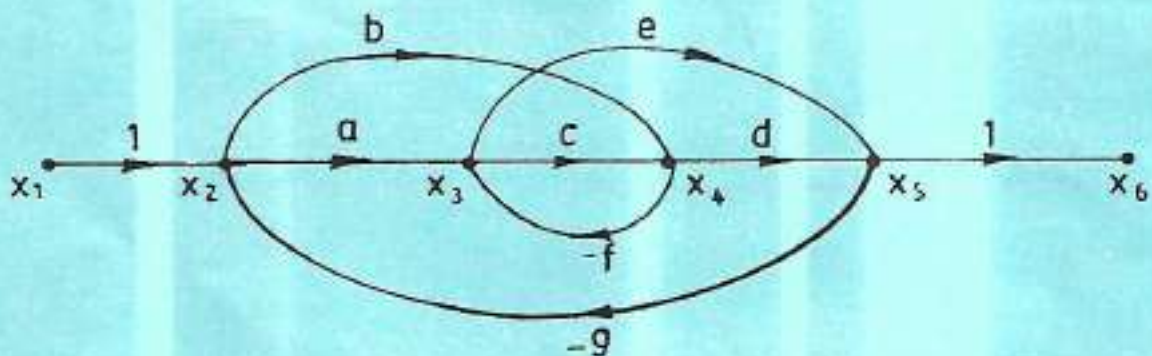   (8 marks)

Fig.2

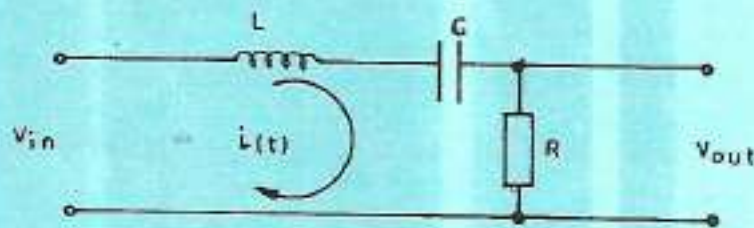(c)   Explain 'system modelling' in control systems.   (2 marks)

(d)   **Figure 3** shows an RLC network.

Fig.3

Determine the:

(i)   transfer function $\dfrac{Vo(s)}{Vin(c)}$;

(ii)   feedback $\dfrac{I(s)}{Vin(c)}$.   (8 marks)

3.   (a)   Define the following terms as used in process control:

    (i)   Control lag;
    (ii)   Process load;
    (iii)   Dead time.   (3 marks)

    (b)   (i)   Draw on a OP-Amp based schematic circuit diagram of an analogue PID controller.
        (ii)   Write the expression for the output of the PID controller in b(i).   (5 marks)

    (c)   Differentiate between electric actuators and solenoid actuators.   (4 marks)

    (d)   With the aid of a labelled schematic diagram, describe the operation of a single activating piston actuator controlled by 2-way pressure valve.   (8 marks)

4.   (a)   (i)   Define process variable as used in process control.
        (ii)   Describe each of the following in process control:

        I.   manipulated variable;
        II.   disturbance variable;
        III.   controlled variable.   (4 marks)

$1 = \frac{1}{k}$

(b) **Figure 4** shows a process control. Draw a labelled block diagram representation of the process control.
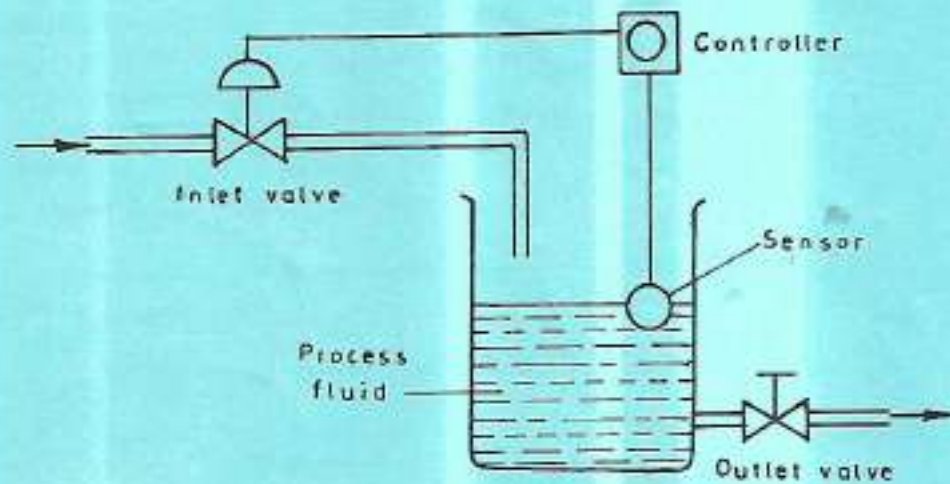
(5 marks)

Fig. 4

(c) (i)   State **two** programmable logic controller (PLC) programming languages.

(ii) Differentiate between digital and analogue PLC input modules citing one example of input device in each case.

(6 marks)

(d) A stepper motor with 200 steps per revolution makes 160 steps clockwise and 440 steps counter clockwise from a reference point. Determine the:
(i)   step angle;
(ii) final shaft angle.

(5 marks)

SECTION B: INSTRUMENTATION

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

5. (a) (i)   State **three** advantages of thermistors over platinum resistance thermometer.
(ii) Explain the principle of operation of resistance temperature sensor.

(7 marks)

(b) A quartz piezo-electric transducer has thickness of 2.1 mm, voltage sensitivity of 0.054 Vm/N and a permittivity of 36×10^{-12} F/m. If the transducer is subjected to a pressure of 60 KN/m², determine the:

(i)   output voltage generated;
(ii) charge sensitivity.

(5 marks)

(c)   Differentiate between absolute pressure and gauge pressure with reference to pressure measurements.
(2 marks)

(d)   With the aid of a labelled diagram, describe measurement of viscosity of fluid using pressure drop method.
(6 marks)

6.   (a)   State **two** types of strain gauges.
(2 marks)

(b)   **Figure 5** shows a strain gauge connected to a wheatstone bridge circuit.
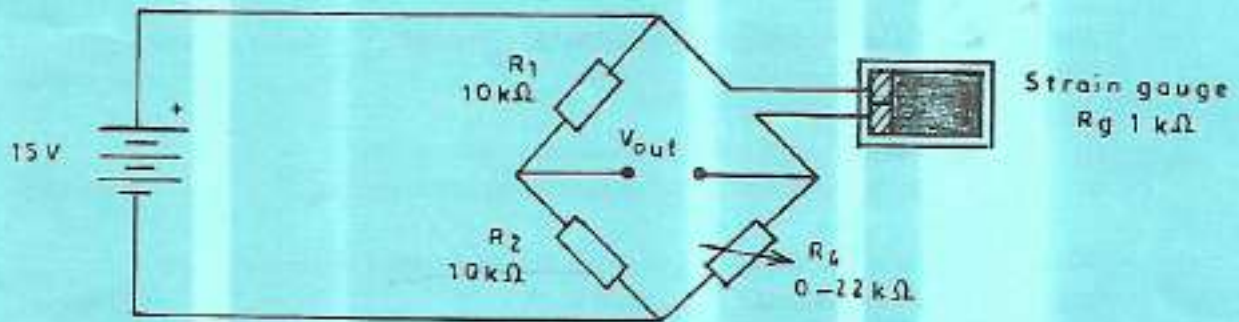

Fig.5

(i)   Describe the operation of the circuit.

(ii)   A strain of 0.0025 m causes the resistance of the strain gauge to change by 100 Ω. Determine the:

    I.   output voltage, V_{out};

    II.   gauge factor.
(9 marks)

(c)   Define 'inductive proximity sensor'.
(1 marks)

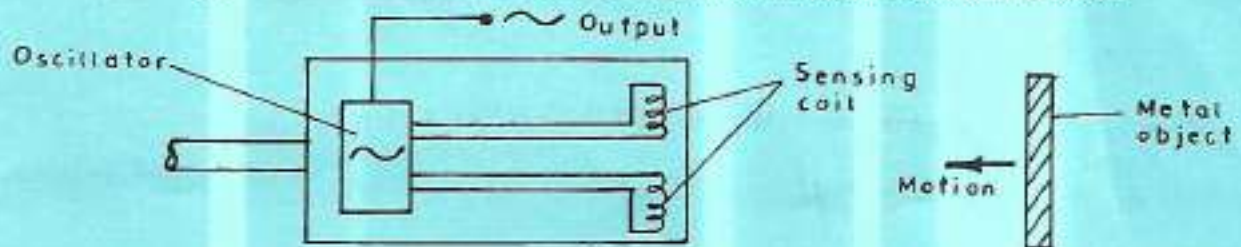(d)   **Figure 6** shows a schematic circuit diagram of an inductive proximity sensor.

Fig.6

(i)   Describe its operation

(ii)   Sketch the output waveforms when the metal object is present and when absent.
(8 marks)

Fig. 8

7. (a) (i) State **three** areas of application of humidity transducers.
       (ii) Differentiate between capacitive and resistive type humidity sensors.
                                                                        (7 marks)

   (b) Outline two maintenance procedures carried out on turbine flowmeter.   (2 marks)

   (c) The manometer pressure difference in a venturi meter is 18 cm for a fluid of density 0.84 g/cm³. The force of gravity is 9.8 m/s². Determine the meter reading.
                                                                        (3 marks)

   (d) With the aid of a labelled diagram, describe the construction of linear variable Differential Transformer (LVDT).
                                                                        (8 marks)

8. (a) (i) State **two** sources of errors in measuring instruments.
       (ii) Describe the controlling type of measuring instruments.   (4 marks)

   (b) With the aid of a labelled diagram, describe the operation of ultrasonic level transducer as used to measure tank liquid level.
                                                                        (7 marks)

   (c) Explain viscousity in fluid citing two properties of a viscous fluid.   (3 marks)

   (d) With the aid of labelled circuit diagrams, differentiate between photoconductive and photo voltaic modes of a photo diode.
                                                                        (6 marks)

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