2501/302 2508/302
2503/302 2509/302
CONTROL SYSTEMS
AND INSTRUMENTATION
Oct./Nov. 2021
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

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

MODULE III

CONTROL SYSTEMS AND INSTRUMENTATION

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Non-programmable Scientific calculator;
Drawing instruments;
Answer booklet.
*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 7 printed pages.

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

SECTION A: CONTROL SYSTEMS

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

1. (a) State **two** differences between open and closed loop control systems. (4 marks)

(b) (i) State **three** merits of block diagram representation of a control system.

(ii) Figure 1 shows a liquid level control system. Determine the transfer function. (8 marks)

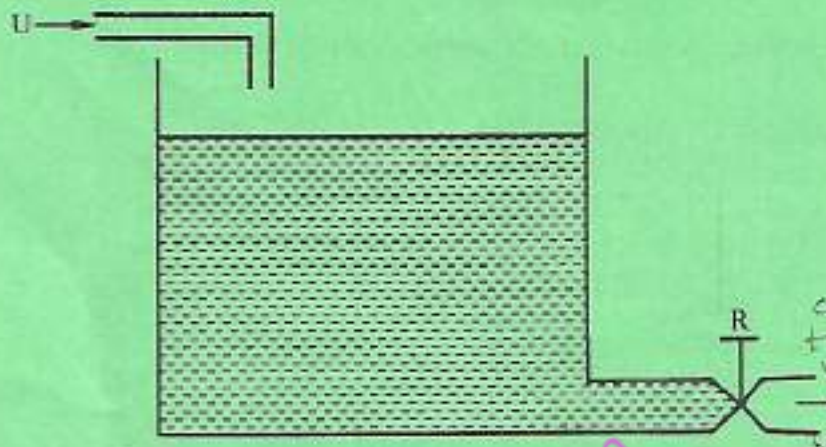

Fig. 1

(c) Figure 2 shows a block diagram representation of control system. Determine its transfer function using block diagram reduction rules. (8 marks)

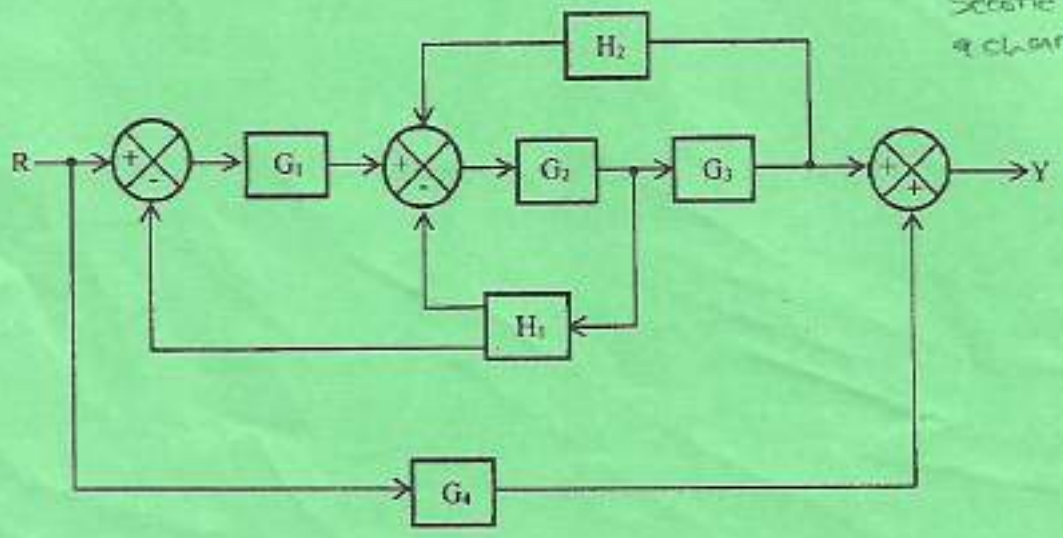

Fig. 2

2. (a) Define each of the following with respect to signal flow graphs:

(i) source node;

(ii) path.

(2 marks)

(b) Figure 3 shows a block diagram representation of a control system.

(i) Draw the equivalent signal flow graph;

(ii) Determine the transfer fraction using Mason's gain formulae.

(8 marks)

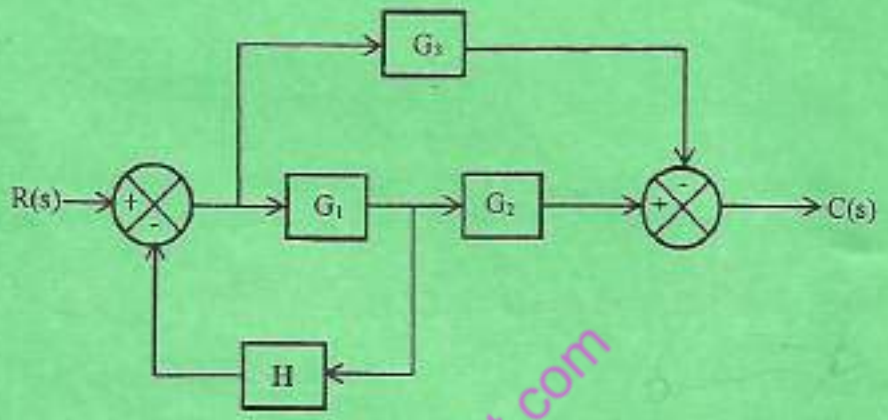

Fig. 3

(c) Distinguish between reverse reset and direct reset with respect to control modes.

(2 marks)

(d) (i) Describe each of the following as used in proportional control modes:

(I) set point;
(II) control point;
(III) offset;
(IV) throttling range.

(ii) Draw a labelled block diagram of a process control system.

(8 marks)

3. (a) State **four** merits of servo motors. (4 marks)

(b) With the aid of a labelled schematic circuit diagram, explain the operation of the armature controlled DC servo motor.

(7 marks)

(c) A control system uses a 4-pole, 50 Hz, induction motor. The no-load slip is 1% and full-load slip is 4%. Determine the:

(i) synchronous speed;

(ii) no-load speed;

(iii) full-load speed.

(6 marks)

(d) Draw the torque-speed characteristic curve of an ac servo motor. (3 marks)

4. (a) State three advantages of a distributed control system over centralized control systems.

(3 marks)

(b) Describe each of the following processes of a SCADA system:

(i) Scanning;
(ii) Conversion;
(iii) Data acquisition.

(3 marks)

(c) A control system consists of limit switches A, B, C and D controlling valves X, Y and Z. To operate valve Y as the main output, either limit switches A and B and valve X are activated while both switch C and valve Z are not activated or switch D and valve X are activated while both switch C and valve Z are not activated:

(i) Write the boolean expression for operating valve Y;

(ii) Draw the ladder logic program for the expression in c(i).

(6 marks)

(d) (i) Figure 4 shows a digital logic diagram for a control system. Draw a ladder diagram for the system. (3 marks)

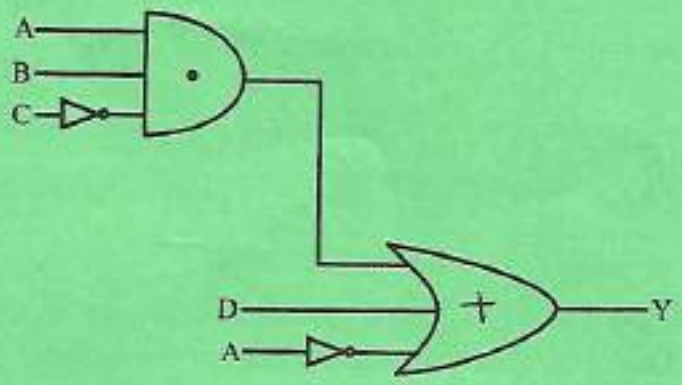

Fig. 4

(ii) Table 1 shows a PLC ladder diagram program. Draw the equivalent mitsubishi PLC instruction listing program. (5 marks)

Table 1

LD X400
ORI X403
LDI X401
OR B
OUT Y400

SECTION B: INSTRUMENTATION

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

5. (a) Define each of the following types of errors:

(i) Equipment errors;
(ii) installation errors;
(iii) personal errors.

(3 marks)

(b) Three 1.5V cells are connected in series to form a battery. Each cell produces an error of ±1%. Determine the error in the voltmeter reading across the battery.

(6 marks)

(c) (i) Outline two factors that determine liquid pressure.

(ii) With the aid of a diagram, explain the operation of a bellow pressure gauge.

(8 marks)

(d) A platinum resistance thermometer has a resistance of 140 Ω at 100°C. The resistance at 0°C is 100 . The resistance increases to 280 Ω when it is in contact with a hot gas. If the temperature coefficient of platinum is 0.0039/°C, determine the temparature of the gas

(3 marks)

6. (a) State **three** limitations of capacitive transducers as used in force sensors. (3 marks)

(b) With the aid of a labelled diagram, explain the operation of a pneumatic load cell.

(7 marks)

(c) An instrumentation system uses a strain gauge with unstrain resistance of 1 kΩ and a gauge factor of 4 fastened to a metal bar. The metal bar is subjected to a stress of 10000 kg/cm^2. The Young's modulus of the metal is 4×10^6 kg/cm^2. Determine the:

(i) strain on the metal bar;
(ii) change in resistance of the strain gauge;
(iii) percentage change in the resistance of the strain gauge.

(7 marks)

(d) Explain seebeck effect with reference to thermocouples. (3 marks)

7. (a) Outline **three** factors considered when designing capacitive type sensor for liquid level measurement. (3 marks)

(b) With the aid of a diagram, explain the operation of a capacitance probe liquid level detector. (7 marks)

(c) Distinguish between head pressure and static pressure. (2 marks)

(d) A pitot static tube is mounted on a vessel moving at a speed of 300 km/h against a wind velocity of 20 km/h. The specific weight of air is 12 N/m^3. Determine the:

(i) vessel velocity (m/s);
(ii) wind velocity (m/s);
(iii) relative velocity of the vessel;
(iv) velocity recorded by the pitot tube;
(v) pressure difference.

(8 marks)

8. (a) Define each of the following as used in photo-electric sensors:

(i) Responsivity;

(ii) Noise equivalent power (NEP);

(iii) Quantum efficiency.

(3 marks)

(b) With the aid of a labelled diagram, describe the operation of the pyroelectric sensor in voltage mode. (7 marks)

(c) Highlight the difference between capacitive and resistive humidity sensors. (2 marks)

(d) With the aid of a labelled diagram, describe the construction of resistance humidity sensor. (8 marks)

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