**Birla Institute of Technology & Science, Pilani**
**Work Integrated Learning Programmes Division**
**Second Semester 2022-2023**
**Comprehensive Examination**
**EC-3 Make-up**

| | |
|---|---|
| Course No. | : ES ZG511 |
| Course Title | : Mechatronics |
| Nature of Exam | : Open Book |
| Weightage | : 40% |
| Duration | : 2 ½ Hours |
| Date of Exam | : 28/05/2023 (AN) |

No. of Pages = 12
No. of Questions = 7

Note to Students:
1. Please follow all the *Instructions to Candidates* given on the cover page of the answer book.
2. All parts of a question should be answered consecutively. Each answer should start from a fresh page.
3. Assumptions made if any, should be stated clearly at the beginning of your answer.

**Q1. SET A**

A packaging line requires to hold the product box and then fix the punch card using riveting pressing. Both operations are performed using two separate double acting cylinder. Two push buttons are provided for this operation. By operating one push button, first holding and then pressing should take place. By operating another push button, holding should be released and pressing rod should move back. Develop a pneumatic circuit for this operation using two double acting cylinders and pressure sequence valve. [8]

**Q1. SET B**

A punching operation involving holding and punching, is to be performed using pneumatic system. Both operations are performed using two separate double acting cylinder. Two push buttons are provided for this operation. By operating one push button, first holding and then punching should take place. By operating another push button, holding should be released and punching rod should move back. Develop a pneumatic circuit for this operation using two double acting cylinders and pressure sequence valve. [8]

**Q1. SET C**

A stamping operation involving holding and stamping, is to be performed using pneumatic system. Both operations are performed using two separate double acting cylinder. Two push buttons are provided for this operation. By operating one push button, first holding and then stamping should take place. By operating another push button, holding should be released and stamping rod should move back. Develop a pneumatic circuit for this operation using two double acting cylinders and pressure sequence valve. [8]

**Q2. SET A**

(a) What are the different type of AC motors available for specific performance and specialties? [1]

(b) What are the strategies to stop a DC motor, detail is with speed vs time graph? [1]

(c) Detail the H-bridge operation and its application on different motors? [1]

**Q2. SET B**

(a) Mention different types of AC motor with their specialties. [1]

(b) For an industrial application, DC motor is utilized. It is required to 'quickly' stop the motor. Detail the methods for the same. [1]

(c) How a H-bridge works for operating different types of DC motor? [1]

**Q2. SET C**

(a) Classify the AC motors based on their performance. [1]

(b) mention the differences between the Dynamic braking and Plugging of DC motors. [1]

(c) What are the functions of H-bridge for DC and stepper motor? [1]

**Q3. SET A**

Develop the mathematical relationship among the Speed, Friction Torque, Torque available, Voltage, and other electrical parameters for a permanently magnet DC motor. [4]

**Q3. SET B**

Develop the mathematical relationship for Friction Torque and available Torque available, with motor speed and voltage, for a permanently magnet DC motor. [4]

**Q3. SET C**

How the Available Torque of a permanent magnet DC motor is dependent on the Speed, Friction torque Voltage, and other electrical parameters. Develop the relation parametrically. [4]

**Q4. SET A**

It is required to develop a differential mobile robot as shown in Fig. Q4a. It uses two similar DC geared motors with speed-reduction ratio of gear box is 4. The mass of theses wheels is 100gm each, with radius of 20 cm, and it can be assumed as a ring element. To achieve desired motion, two solid caster wheel (spherical) assemblies are provided as the opposite end, each having 180gm mass & 20 cm radius. The whole assembly is mounted on a circular platform. The total mass of this robot is equal to 1 Kg and their combined CG is maintained at the center of the platform. The overall moment of inertia (MOI) of the gearbox and motor can be neglected. It is required to run this robot carrying a mass of 1.5 Kg, in a trapezoidal velocity profile as shown in Fig. Q4b, on a linear path. For this application, compute the followings, [MOI for ring=mass×radius$^2$, MOI for sphere=2/5×mass×radius$^2$]

(i) MOI of both wheels, reflected on motors side [2]

(ii) MOI of both caster wheels, reflected on motors side [2]

(iii) Total MOI, reflected on motors side. [1]

(iv) Maximum Torque required for given velocity profile (Fig. Q4b). Neglect the frictional torques. [1]

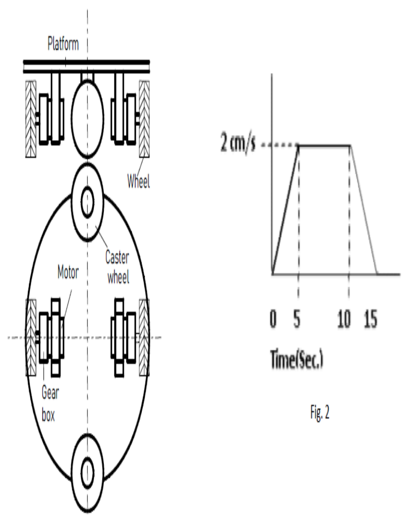



**Fig. Q4a**

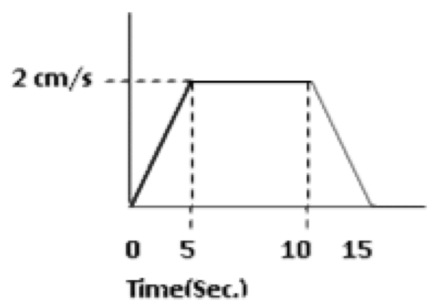



**Fig. Q4b**

**Q4. SET B**

It is required to develop a differential mobile robot as shown in Fig. Q4a. It uses two similar DC geared motors with speed-reduction ratio of gear box is 5. The mass of theses wheels is 200gm each, with radius of 50 cm, and these can be assumed as a ring element. To achieve desired motion, two solid caster wheel (spherical) assemblies are provided as the opposite end, each having 150gm mass & 50 cm radius. The whole assembly is mounted on a circular platform. The total mass of this robot is equal to 2 Kg and their combined CG is maintained at the center of the platform. The overall moment of inertia (MOI) of the gearbox and motor can be neglected. It is required to run this robot carrying a mass of 2 Kg, in a trapezoidal velocity profile as shown in Fig. Q4b, on a linear path. For this application, compute the followings, [MOI for ring=mass×radius$^2$, MOI for sphere=2/5×mass×radius$^2$]

(i) MOI of both wheels, reflected on motors side [2]

(ii) MOI of both caster wheels, reflected on motors side [2]

(iii) Total MOI, reflected on motors side. [1]

(iv) Maximum Torque required for given velocity profile (Fig. Q4b). Neglect the frictional torques. [1]

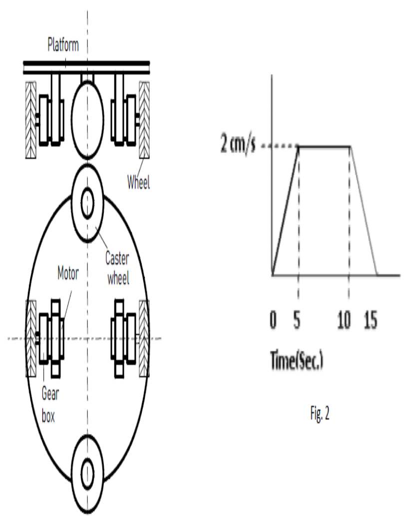



**Fig. Q4a**

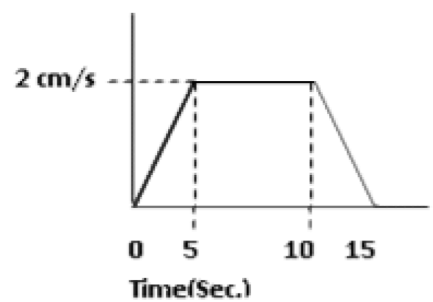



**Fig. Q4b**

**Q4. SET C**

It is required to develop a differential mobile robot as shown in Fig. Q4a. It uses two similar DC geared motors with speed-reduction ratio of gear box is 5. The mass of theses wheels is 150gm each, with radius of 30 cm, and it can be assumed as a ring element. To achieve desired motion, two solid caster wheel (spherical) assemblies are provided as the opposite end, each having 190gm mass & 30 cm radius. The whole assembly is mounted on a circular platform. The total mass of this robot is equal to 2.5 Kg and their combined CG is maintained at the center of the platform. The overall moment of inertia (MOI) of the gearbox and motor can be neglected. It is required to run this robot carrying a mass of 4 Kg, in a trapezoidal velocity profile as shown in Fig. Q4b, on a linear path. For this application, compute the followings, [MOI for ring=mass×radius$^2$, MOI for sphere=2/5×mass×radius$^2$]

(i) MOI of both wheels, reflected on motors side [2]

(ii) MOI of both caster wheels, reflected on motors side [2]

(iii) Total MOI, reflected on motors side. [1]

(iv) Maximum Torque required for given velocity profile (Fig. Q4b). Neglect the frictional torques. [1]

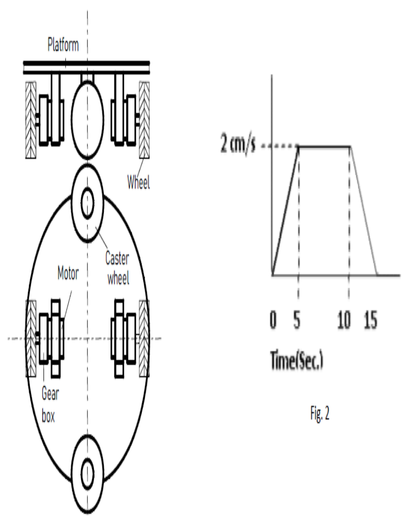



**Fig. Q4a**

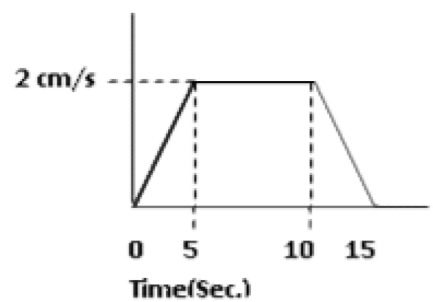
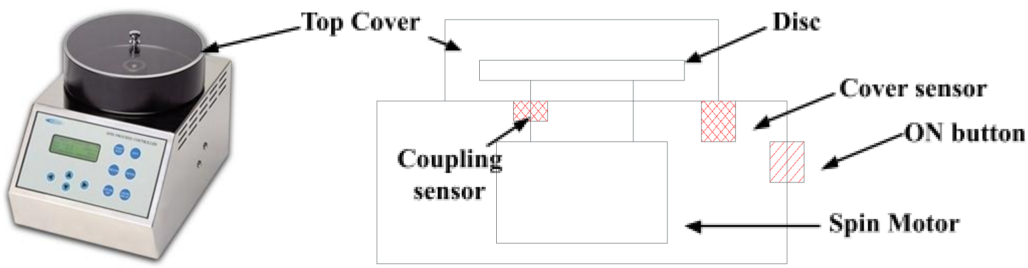



**Fig. Q4b**

**Q5. SET A**

(a) In the fabrication process of a microfluidic system, a spin coater is used to deploy uniform coting of photoresist material on silicon wafer, as shown in Fig.Q5.




**FigQ5: Spin coater with sensors and actuator**

The spin coater uses a high rpm motor to spin the Silicon disc. There are sensors to detect, (i) closing of top cover and (ii) proper coupling of disc with the spin head and the ambient temperature. Create a digital logic circuit that automates the spin motor in the given conditions below, [3]

- First condition: Start button is ON, top cover is closed and proper coupling of disc with the spin head is detected, ambient temperature is permissible.
- Second condition: Start button is ON, top cover is open and proper coupling of disc with the spin head is not detected (or, there is no disc), ambient temperature is permissible or non-permissible.

The states of the sensors are defined as,

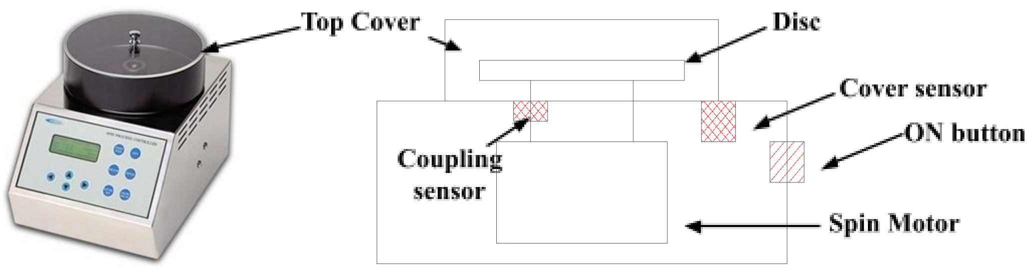
| Sensor | State '1' | State '0' |
|---|---|---|
| Start button | ON | OFF |
| Top cover | Closed | Open |
| Ambient temperature | Permissible | Non- permissible |

(b) Simplify the following Boolean expression using Karnaugh map. [3]

$$Y = A\,B\,C\,D + A'\,B\,C\,D + A\,B'\,C\,D + A'\,B\,C'\,D + AB'C'D' + A'B'C'D'$$

**Q5. SET B**

(a) In the fabrication process of a microfluidic system, a spin coater is used to deploy uniform coting of photoresist material on silicon wafer, as shown in Fig.Q5.

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The states of the sensors are defined as,

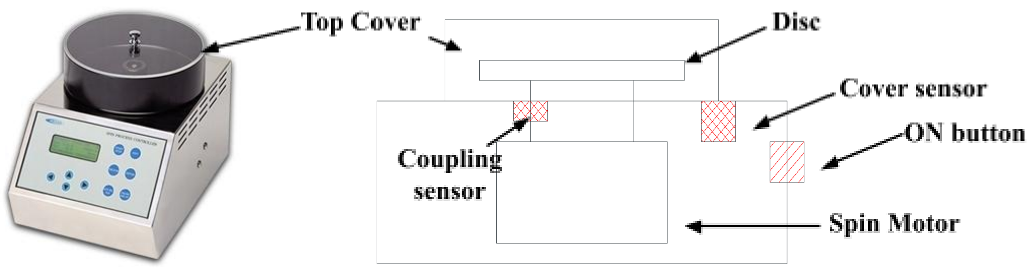
| **Sensor** | **State '1'** | **State '0'** |
|---|---|---|
| Start button | ON | OFF |
| Top cover | Open | Closed |
| Ambient temperature | Non-Permissible | Permissible |

(b) Simplify the following Boolean expression using Karnaugh map. [3]

$$Y = A\,B\,C\,D + A'\,B'\,C\,D + A\,B'\,C'\,D + A\,B\,C'\,D' + A'BCD + A'B'C'D'$$

**Q5. SET C**

(a) In the fabrication process of a microfluidic system, a spin coater is used to deploy uniform coting of photoresist material on silicon wafer, as shown in Fig.Q5.




**FigQ5: Spin coater with sensors and actuator**

The spin coater uses a high rpm motor to spin the Silicon disc. There are sensors to detect, (i) closing of top cover and (ii) proper coupling of disc with the spin head and the ambient temperature. Create a digital logic circuit that automates the spin motor in the given conditions below, [3]

- First condition: Start button is ON, top cover is closed and proper coupling of disc with the spin head is detected, ambient temperature is permissible.
- Second condition: Start button is ON, top cover is open and proper coupling of disc with the spin head is not detected (or, there is no disc), ambient temperature is permissible or non-permissible.

The states of the sensors are defined as,

| **Sensor** | **State '1'** | **State '0'** |
|---|---|---|
| Start button | OFF | ON |
| Top cover | Closed | Open |
| Ambient temperature | Permissible | Non- permissible |

(b) Simplify the following Boolean expression using Karnaugh map. [3]

$$Y = A\,B\,C\,D + A'\,B'\,C\,D + A\,B\,C'\,D' + A'\,B'\,C'\,D + AB'C'D' + A'B'C'D'$$

**Q6. SET A**

For a PLC-ladder logic, complete signal diagram is given in Fig Q6. Prepare a Ladder logic as per the given signal diagram. All the inputs are push button type. The output Y3 should be auto switch off after a fixed time duration. Input X3 is for Master-reset. Use Timer, Counter and Latching in the circuit. [7]

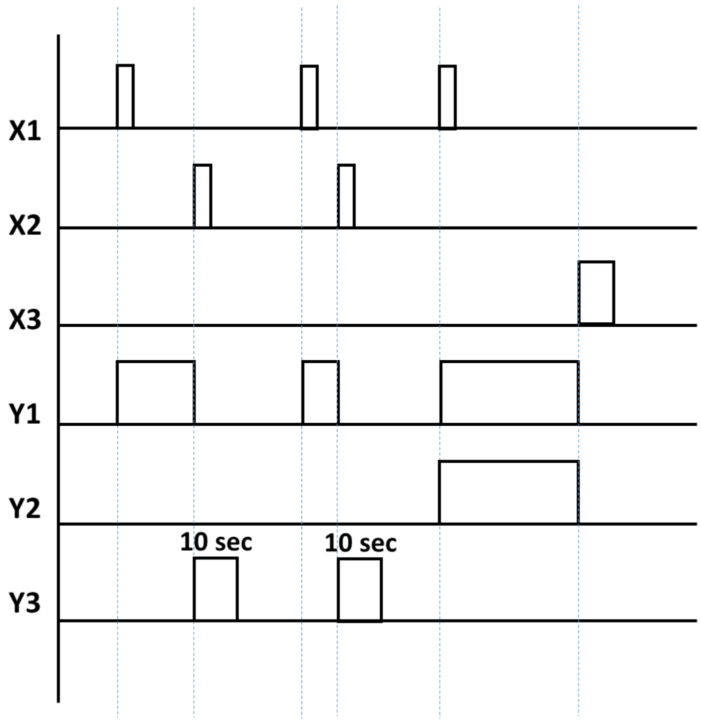



**Fig Q6**

**Q6. SET B**

For a PLC-ladder logic, complete signal diagram is given in Fig Q6. Prepare a Ladder logic as per the given signal diagram. All the inputs are push button type. The output Y3 should be auto switch off after a fixed time duration. Input X3 is for Master-reset. Use Timer, Counter and Latching in the circuit. [7]

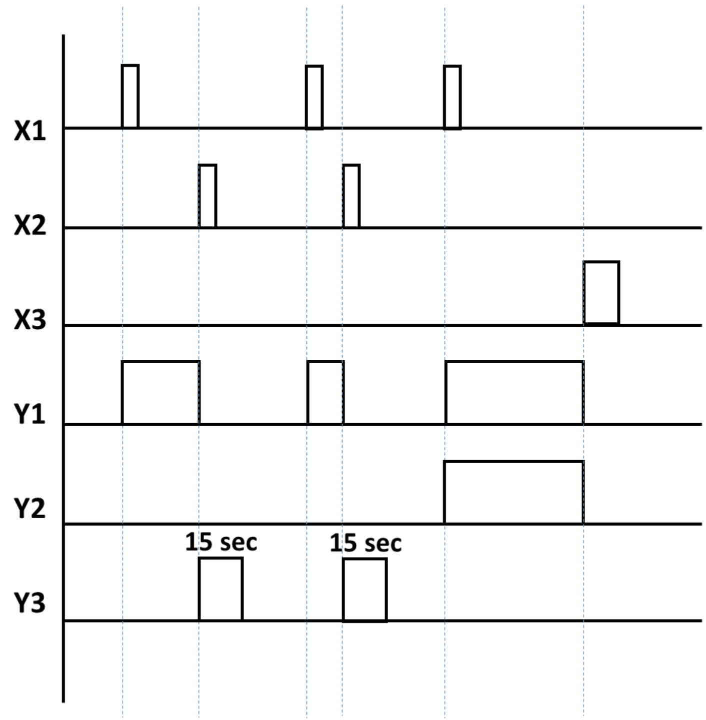



**Fig Q6**

**Q6. SET C**

For a PLC-ladder logic, complete signal diagram is given in Fig Q6. Prepare a Ladder logic as per the given signal diagram. All the inputs are push button type. The output Y3 should be auto switch off after a fixed time duration. Input X3 is for Master-reset. Use Timer, Counter and Latching in the circuit. [7]

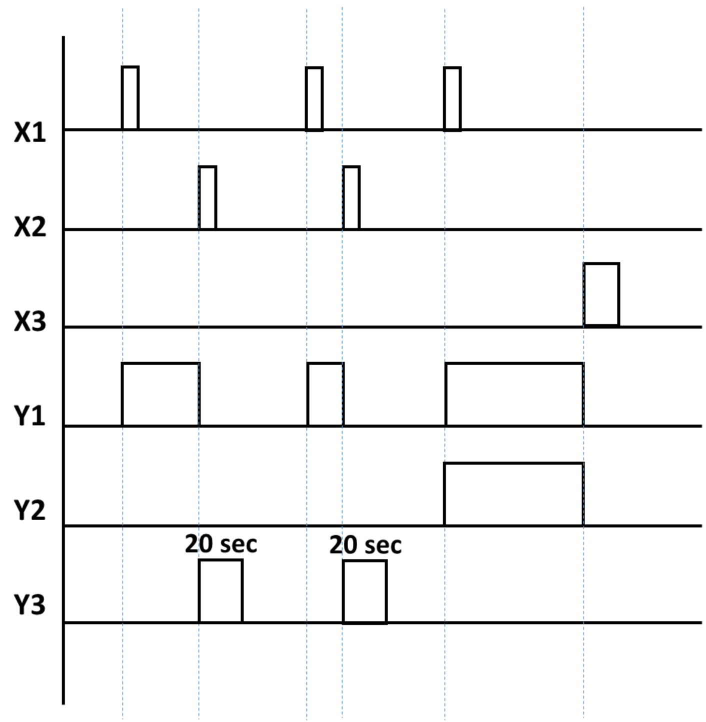



**Fig Q6**

**Q7. SET A**

An air conditioning system is working on two-mode control system. The room temperature is to be maintained at 23 deg. C, with a neutral zone of ±10%. The room temperature is sensed by an RTD with a lag of 0.5 min. When the cooling system in ON, the rate of cooling of the room is 3 deg.C drop per minute. When the cooling system is OFF, the temperature rises with a rate of 2 deg.C per min. Plot the temperature variation curve and find the oscillation period of the temperature. Also show the ON/OFF cycle cooling system on the time graph. [6]

**Q7. SET B**

An air conditioning system is working on two mode control system. The room temperature is to be maintained at 25 deg. C, with a neutral zone of ±10%. The room temperature is sensed by an RTD with a lag of 0.5 min. When the cooling system in ON, the rate of cooling of the room is 4 deg.C drop per minute. When the cooling system is OFF, the temperature rises with a rate of 3 deg.C per min. Plot the temperature variation curve and find the oscillation period of the temperature. Also show the ON/OFF cycle cooling system on the time graph. [6]

**Q7. SET C**

An air conditioning system is working on two mode control system. The room temperature is to be maintained at 24 deg. C, with a neutral zone of ±10%. The room temperature is sensed by an RTD with a lag of 0.5 min. When the cooling system in ON, the rate of cooling of the room is 4 deg.C drop per minute. When the cooling system is OFF, the temperature rises with a rate of 2 deg.C per min. Plot the temperature variation curve and find the oscillation period of the temperature. Also show the ON/OFF cycle cooling system on the time graph. [6]