Program: B.Sc. Engg. (ME / IPE)
Semester: 4th Sem.

Date: 24 May 2024
Time: 10:00 am – 01:00 pm

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)

DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

Semester Final Examination
Course No.: ME 4407
Course Title: Measurement, Instrumentation and Control

Summer Semester, A. Y. 2022-2023
Time: 3 Hours 00 Min(s)
Full Marks: 150

There are 6 (Six) questions. Answer all the questions.
Marks of each question and corresponding CO and PO are written in brackets.
Do not write on this question paper.

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1. a) What are the main elements of a measurement system? Explain with respect to a speed measuring system. **(13)** (CO1) (PO2)

   b) Suppose you are a recently appointed instrumentation engineer at Tesla. You are asked to purchase 50 measurement devices for your department. While making the purchase, you need to consider the static and dynamic characteristics of the instruments. **(12)** (CO1) (PO2)
   i)What are the static characteristics of an instrument?
   ii) Between a high precision-low accuracy and Low precision-high accuracy device, which would you choose? Explain with appropriate diagrams.

2. a) In a particular industrial situation, a chromel-alumel thermocouple with chromel-alumel extension wires is used to measure the temperature of a fluid. In connecting this measurement system, the instrumentation engineer responsible has inadvertently interchanged the extension wires from the thermocouple (such that the chromel wire is connected to the alumel extension lead wire, etc.). **(13)** (CO2) (PO2)
   The open ends of the extension leads are held at a reference temperature of 0°C and are connected to a voltmeter, which measures an e.m.f of 18.75 mV. If the junction between the thermocouple extension wires is at a temperature of 38°C.
   i) What temperature of fluid is indicated?
   ii) What is the true fluid temperature?

   b) Explain the working principle of a hall effect sensor. With the help of appropriate sketches, explain how the hall effect sensor can be used to build a metal detector. **(12)** (CO2) (PO2)

3. a) What is the operational range of a Pirani thermal-conductivity gauge, and elucidate its underlying working principle in detail? **(13)** (CO2) (PO2)

   b) Design a measurement system incorporating the necessary sensors and actuators for a wearable device aimed at monitoring the user's posture. The system should provide real-time feedback to encourage proper alignment and help prevent back pain and related musculoskeletal issues. **(12)** (CO2) (PO2)

4. a) Calculate the digital output of 7.5V using the Successive-Approximation ADC method (12-bit A/D with range -1 to 10V). Also, calculate the error (if any). In order to reduce the error, what are the possible ways that can be implemented on the above method. **(15)** (CO1) (PO2)

b) Write the Boolean expression and draw the PLC ladder logic diagram for the control system shown in Figure 1. **(10)** (CO1) (PO2)

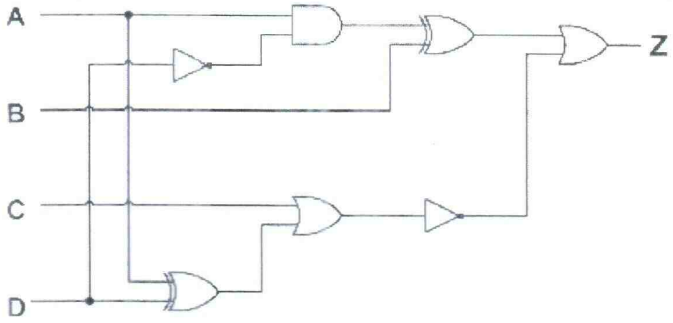

Figure 1 (Question 4(b))

5. Consider a pneumatic system with two cylinders A and B with limit switches a0, a1, b0 and b1 detecting the limits of the piston rod movements (Figure 1), with the requirement to give the sequence: A+ B+ B- A- **(25)** (CO3) (PO2)

That is, piston A first moves out to full stroke. After that, piston B moves out to full stroke, then it retracts. Finally, piston A retracts.

Figure 1 (Question 5)

i) Describe the challenges associated with implementing the above sequence using 3/2 roller lever valves (without idle return). Include a diagram to illustrate these challenges.

ii) How can these challenges be resolved mechanically? Provide a detailed explanation and a sequential flow diagram to demonstrate the solution.

6. A chemical reactor is engineered to maintain its temperature within a specific range using two different cooling systems: a cooling water system and a refrigeration system. The control logic for this system operates as follows: **(25)** (CO4) (PO2)

- When the reactor temperature rises above the setpoint, the temperature controller output (CO) starts increasing.
- 0% to 50% CO: The cooling water valve (Valve A) starts to open proportionally to cool the reactor using the cooling water system.
  - At 0% CO, Valve A is fully closed.
  - At 50% CO, Valve A is fully open.
- 50% to 100% CO: The refrigeration valve (Valve B) starts to open proportionally to provide additional cooling.
  - At 50% CO, Valve B starts to open.
  - At 100% CO, Valve B is fully open.

Please address the following questions based on the above control logic:

i) What type of control loop can be used to maintain the temperature within the specified range using the described control logic? Provide an explanation supported by a necessary diagram.

ii) Which control algorithm is most suitable for this control loop, and why?

iii) Is Time Proportional Control necessary for this scenario? Justify your answer with a suitable diagram.

Thermocouple Table

Type E: chromel–constantan
Type J: iron–constantan
Type K: chromel–alumel
Type N: nicrosil–nisil
Type S: platinum/10% rhodium–platinum
Type T: copper–constantan

Temperature (°C)	Type E	Type J	Type K	Type N	Type S	Type T
20	1.192	1.019	0.798	0.525	0.113	0.789
30	1.801	1.536	1.203	0.793	0.173	1.196
40	2.419	2.058	1.611	1.064	0.235	1.611
50	3.047	2.585	2.022	1.339	0.299	2.035
60	3.683	3.115	2.436	1.619	0.365	2.467
70	4.329	3.649	2.850	1.902	0.432	2.908
80	4.983	4.186	3.266	2.188	0.502	3.357
90	5.646	4.725	3.681	2.479	0.573	3.813
100	6.317	5.268	4.095	2.774	0.645	4.277
110	6.996	5.812	4.508	3.072	0.719	4.749
120	7.683	6.359	4.919	3.374	0.795	5.227
130	8.377	6.907	5.327	3.679	0.872	5.712
140	9.078	7.457	5.733	3.988	0.950	6.204
150	9.787	8.008	6.137	4.301	1.029	6.702
160	10.501	8.560	6.539	4.617	1.109	7.207
170	11.222	9.113	6.939	4.936	1.190	7.718
180	11.949	9.667	7.338	5.258	1.273	8.235
190	12.681	10.222	7.737	5.584	1.356	8.757
200	13.419	10.777	8.137	5.912	1.440	9.286
210	14.161	11.332	8.537	6.243	1.525	9.820
220	14.909	11.887	8.938	6.577	1.611	10.360
230	15.661	12.442	9.341	6.914	1.698	10.905
240	16.417	12.998	9.745	7.254	1.785	11.456
250	17.178	13.553	10.151	7.596	1.873	12.011
260	17.942	14.108	10.560	7.940	1.962	12.572
270	18.710	14.663	10.969	8.287	2.051	13.137
280	19.481	15.217	11.381	8.636	2.141	13.707
290	20.256	15.771	11.793	8.987	2.232	14.281
300	21.033	16.325	12.207	9.340	2.323	14.860
310	21.814	16.879	12.623	9.695	2.414	15.443
320	22.597	17.432	13.039	10.053	2.506	16.030
330	23.383	17.984	13.456	10.412	2.599	16.621
340	24.171	18.537	13.874	10.772	2.692	17.217
350	24.961	19.089	14.292	11.135	2.786	17.816
360	25.754	19.640	14.712	11.499	2.880	18.420
370	26.549	20.192	15.132	11.865	2.974	19.027
380	27.345	20.743	15.552	12.233	3.069	19.638
390	28.143	21.295	15.974	12.602	3.164	20.252
400	28.943	21.846	16.395	12.972	3.260	20.869
410	29.744	22.397	16.818	13.344	3.356	
420	30.546	22.949	17.241	13.717	3.452	
430	31.350	23.501	17.664	14.091	3.549	
440	32.155	24.054	18.088	14.467	3.645	
450	32.960	24.607	18.513	14.844	3.743	
460	33.767	25.161	18.938	15.222	3.840	
470	34.574	25.716	19.363	15.601	3.938	

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Temperature (°C)	Type E	Type J	Type K	Type N	Type S	Type T
480	35.382	26.272	19.788	15.981	4.036	
490	36.190	26.829	20.214	16.362	4.135	
500	36.999	27.388	20.640	16.744	4.234	
510	37.808	27.949	21.066	17.127	4.333	
520	38.617	28.511	21.493	17.511	4.432	
530	39.426	29.075	21.919	17.896	4.532	
540	40.236	29.642	22.346	18.282	4.632	
550	41.045	30.210	22.772	18.668	4.732	
560	41.853	30.782	23.198	19.055	4.832	
570	42.662	31.356	23.624	19.443	4.933	
580	43.470	31.933	24.050	19.831	5.034	
590	44.278	32.513	24.476	20.220	5.136	
600	45.085	33.096	24.902	20.609	5.237	
610	45.891	33.683	25.327	20.999	5.339	
620	46.697	34.273	25.751	21.390	5.442	
630	47.502	34.867	26.176	21.781	5.544	
640	48.306	35.464	26.599	22.172	5.648	
650	49.109	36.066	27.022	22.564	5.751	
660	49.911	36.671	27.445	22.956	5.855	
670	50.713	37.280	27.867	23.348	5.960	
680	51.513	37.893	28.288	23.740	6.064	
690	52.312	38.510	28.709	24.133	6.169	
700	53.110	39.130	29.128	24.526	6.274	
710	53.907	39.754	29.547	24.919	6.380	
720	54.703	40.382	29.965	25.312	6.486	
730	55.498	41.013	30.383	25.705	6.592	
740	56.291	41.647	30.799	26.098	6.699	
750	57.083	42.283	31.214	26.491	6.805	
760	57.873	42.922	31.629	26.885	6.913	
770	58.663	43.563	32.042	27.278	7.020	
780	59.451	44.207	32.455	27.671	7.128	
790	60.237	44.852	32.866	28.063	7.236	
800	61.022	45.498	33.277	28.456	7.345	
810	61.806	46.144	33.686	28.849	7.454	
820	62.588	46.790	34.095	29.241	7.563	
830	63.368	47.434	34.502	29.633	7.672	
840	64.147	48.076	34.908	30.025	7.782	
850	64.924	48.717	35.314	30.417	7.892	
860	65.700	49.354	35.718	30.808	8.003	
870	66.473	49.989	36.121	31.199	8.114	
880	67.245	50.621	36.524	31.590	8.225	
890	68.015	51.249	36.925	31.980	8.336	
900	68.783	51.875	37.325	32.370	8.448	
910	69.549	52.496	37.724	32.760	8.560	
920	70.313	53.115	38.122	33.149	8.673	
930	71.075	53.729	38.519	33.538	8.786	

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