

KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 4th Year 1st Term Examination, 2023

MTE 4011

(Machine Learning)

Time: 3.00 Hrs.

Total Marks: 210

- N.B.:** i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.

SECTION-A

- 1(a) Define classification, regression, and logistic regression in short. Differentiate between the concepts: “classification vs. regression” and “regression vs. logistic regression”. 12
- 1(b) What do you understand by linear problem and non-linear problem in the context of machine learning? Write down the assumptions of linear regression. 10
- 1(c) Explain how learning rate impacts the convergence of a model. What potential issues can arise from choosing a learning rate that is too high or too low? 08
- 1(d) Explain the difference between batch gradient descent and mini-batch gradient descent. 05

- 2(a) Consider the following cost function and hypothesis for linear regression. Derive the normal equation, $\theta = (X^T X)^{-1} X^T Y$ to get the values of vector θ . 15

$$J(\theta) = \frac{1}{2m} \sum_{i=1}^m (h_{\theta}(x_i) - y_i)^2$$

$$h_{\theta}(x_i) = \theta_0 + \theta_1 x_{1,i} + \dots + \theta_n x_{n,i}$$

- 2(b) What is Bayes theorem? Shortly describe Naïve Bayes classifier. 10
- 2(c) Write short notes on (i) Covariance and (ii) Correlation. Why is it necessary to compute a covariance matrix for principle component analysis? 10
- 3(a) What are support vectors in support vector machine (SVM)? How does linear SVM works? Explain. 10
- 3(b) Consider the following training dataset, where A, B, and C are the three binary attributes, and D is a binary class label. 15

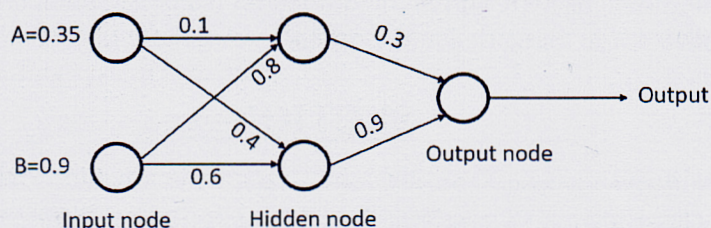
Instance	A	B	C	D
1	0	0	0	0
2	0	0	1	0
3	0	1	0	1
4	0	1	1	1
5	1	0	1	1
6	1	0	1	1
7	1	1	0	0
8	1	1	0	0

- (i) Using ID3 algorithm, build a decision tree for this classification problem
(ii) Use the built decision tree to classify two samples below:

Instance	A	B	C	D
9	1	1	1	?
10	1	0	0	?

- 3(c) What is meant by regularization in machine learning? How does it help in prevent overfitting? 10

- 4(a) What is back propagation in neural networks? Write down its role in minimizing the error rate. 07
- 4(b) Explain how pruning can be used to prevent overfitting in decision trees. 10
- 4(c) What do you mean by feed forward network? Write down the roles of activation function in artificial neural network (ANN). Also name some activation functions used in ANNs. 08
- 4(d) Consider the simple neural network in figure below. 10
- (i) Perform forward pass on the network
- (ii) Perform backward pass on the network.



SECTION-B

- 5(a) Compare convex and non-convex optimization problems in machine learning. Provide examples of each. 10
- 5(b) Discuss the impact of non-convexity on gradient based optimization algorithms commonly used in machine learning, such as gradient decent. 10
- 5(c) Is the K-means clustering algorithm guaranteed to converge? Support your answer with proper mathematical explanation. What will be the remedy if K-means clustering algorithm get stuck in bad local minima? 15
- 6(a) Explain the concept of bias-variance trade-off in machine learning. How does it affect model performance? 10
- 6(b) Discuss about some commonly metrics for measuring dissimilarities among clusters. Outline differences between Hierarchical clustering and K-means clustering. 10
- 6(c) Suppose you have a distance matrix from a dataset containing information about six products availability and demand. Now cluster these products and draw the dendrogram using Hierarchical Agglomerative clustering with single linkage method. The distance matrix is shown below. 15

	P1	P2	P3	P4	P5	P6
P1	0					
P2	0.71	0				
P3	5.66	4.95	0			
P4	3.61	2.92	2.24	0		
P5	4.24	3.54	1.41	1.00	0	
P6	3.20	2.50	2.50	0.50	1.12	0

- 7(a) What is K nearest neighbor (KNN) algorithm? How does the choice of K impact the performance of KNN model? 10
- 7(b) Suppose, you have data from survey and objective testing with attributes (Product durability and strength) to classify whether a special product is good or bad. Here is four training samples: 15

Product Durability X_1 (sec)	Product Strength X_2 (kg/sq. mt.)	Classification Y
7	7	Bad
7	4	Bad
3	4	Good
1	4	Good

Now the factory produces a new product that pass lab test with $X_1 = 3$ and $X_2 = 7$. Apply KNN to classify this new product using $K=3$. Now, for the same scenario use $K =2$ and put your comment on the classification outcome.

- 7(c) What is meant by curse of dimensionality? Explain how it can lead machine learning model to overfitting. 10
- 8(a) Discuss about positive aspects of using dimensionality reduction on a dataset. 10
- 8(b) Why we calculate covariance when we could just plot two values to see their relationship? Why is it necessary to compute a covariance matrix for Principle component analysis? 10
- 8(c) Suppose you have a dataset with two variables, x_1 and x_2 . And the data points are as follows: 15

Features	P1	P2	P3	P4
x_1	2	3	4	5
x_2	4	6	8	10

Find the Eigenvalues through covariance matrix. Determine which Eigenvalue corresponds to the first principle component and why?

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KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY
Department of Mechatronics Engineering
B. Sc. Engineering 4th Year 1st Term Examination, 2022
MTE 4033
(Advanced Vehicle Technology)

Time: 3 Hours

Total Marks: 210

- N.B.:** i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.
iii) Assume reasonable data if any missing.

SECTION-A

- 1(a) Outline the major components of an automobile. Explain the functions of each of them. 12
- 1(b) What are the basic types of piston ring? Why are they used in modern engine? 08
- 1(c) Why suction valve is larger than the exhaust valve? Mention the basic purpose of antifreeze in the cooling system. 08
- 1(d) Draw the valve timing diagram of a four-stroke diesel engine. 07
- 2(a) Describe electronic fuel injection system with necessary figure. 12
- 2(b) Explain the working of Planetary gears in overdrive. How reverse gear mechanism can be obtained by Planetary gear? 15
- 2(c) State the purposes of the transmission of an automobile. Why torque converter is used in automatic transmission vehicle? 08
- 3(a) Why is cooling and lubrication of an IC engine necessary? Briefly describe water cooling system with its advantages. 12
- 3(b) Discuss the merits and demerits of radial tyre over a bias ply tyre. 07
- 3(c) Why clutch system is used in vehicle? Describe the working principle of a diaphragm-spring clutch with neat sketch. 10
- 3(d) What is power steering? Mention its advantages over normal steering. 06
- 4(a) Why springs are used in the suspension system? Describe the working of a shock absorber with neat sketch. 10
- 4(b) Write down the importance of tyre grading. Describe the causes and remedies of excessive tyre wear. 10
- 4(c) Describe the operation mechanism of synchronization in manual gear box. Why synchronizer is not used in back gear? 15

SECTION-B

- 5(a) Define Autotronics. Explain the significance of electronics for improving the overall performance of automotive vehicle over the years. 10
- 5(b) Classify automotive safety devices with necessary examples. 10

- 5(c) What is Electronic Control Unit (ECU)? What are the components of ECU? Briefly explain the functionality of each component. 15
- 6(a) What is an Anti-lock Braking System (ABS)? How does an ABS work? Can ABS completely eliminate skidding during braking? 15
- 6(b) Suppose you are an employee at Tesla. You are assigned to model ABS for automotive vehicle. Now develop a mathematical model for simulating ABS in automotive vehicle. Then using this mathematical model, draw a proper block diagram of the overall system. Finally, explain how this system is working. 20
- 7(a) What is Cruise Control? What are the limitations and considerations when using Cruise Control? Can Cruise Control contribute to fuel efficiency? 10
- 7(b) Explain – “Automatic Cruise Control is an excellent example of a feedback control system in modern vehicles.” 05
- 7(c) Write short notes on: (i) Traction Control Systems (TCS), (ii) Electronic Stability Program (ESP). 10
- 7(d) How does ABS interact with other vehicle control systems, such as TCS and ESP? 10
- 8(a) What is a hybrid vehicle and fuel cell vehicle? What are the advantages of hybrid vehicles? 10
- 8(b) What do you mean by Autonomous Navigation? What are the functions of the following in sensing for autonomous driving: (i) GPS/IMU, (ii) LiDAR, and (iii) Cameras. 15
- 8(c) Briefly explain the term ‘Perception’ in context of autonomous driving. How Localization and Path Planning are achieved during autonomous driving? 10

KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 4th Year 1st Term Examination, 2023

MTE 4101

(Industrial Automation)

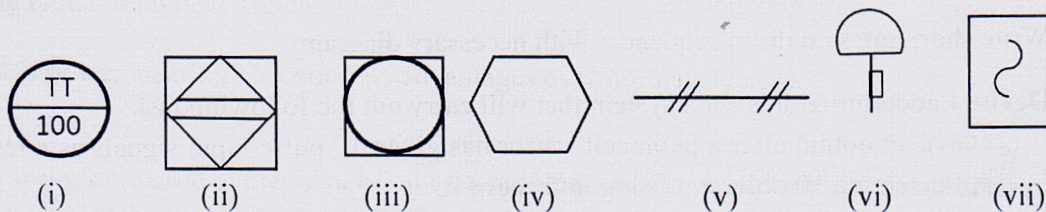
Time: 3.00 Hrs.

Total Marks: 210

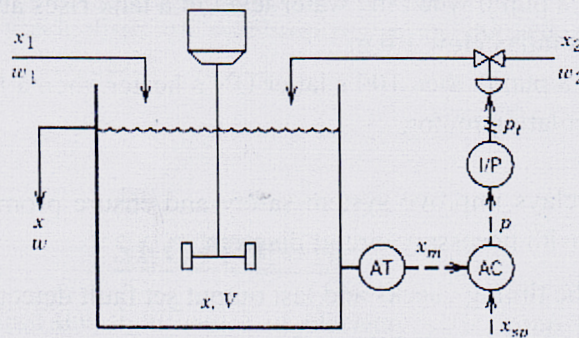
- N.B.:** i) Answer any THREE questions from each section in separate scripts.
 ii) Figures in the right margin indicate full marks.

SECTION-A

- 1(a) What is meant by industrial automation? How does it differ from mechanization? 06
- 1(b) Briefly explain different types of industrial automation with proper example. 12
- 1(c) The main purpose of a company is to make profit. How does automation increases profit? Explain. 10
- 1(d) Draw the automation pyramid mentioning all its levels and related components. 07
- 2(a) What is meant by data communication? Why does industrial automation require it? 06
- 2(b) Define the following terms: (i) Node (ii) Network media (iii) Protocol (iv) Bus topology and (v) Router 12
- 2(c) Briefly explain PROFIBUS and PROFINET. Relatively compare them. 14
- 2(d) Mention the commonly used network connectors. 03
- 3(a) Define sensor, transducer, and transmitter. What are the different standard signal levels in industrial automation system? 10
- 3(b) What are the common process variables measured in industry? Mention at least two sensors to measure these variables. 10
- 3(c) Suppose you are going to measure flow rate of a clear liquid flowing through a pipe of dia 40 cm. Without any flow rate reduction during measurement, which type of sensor will you suggest? Briefly explain its working procedure. 15
- 4(a) What does it mean by the following symbols according to ISA? 14



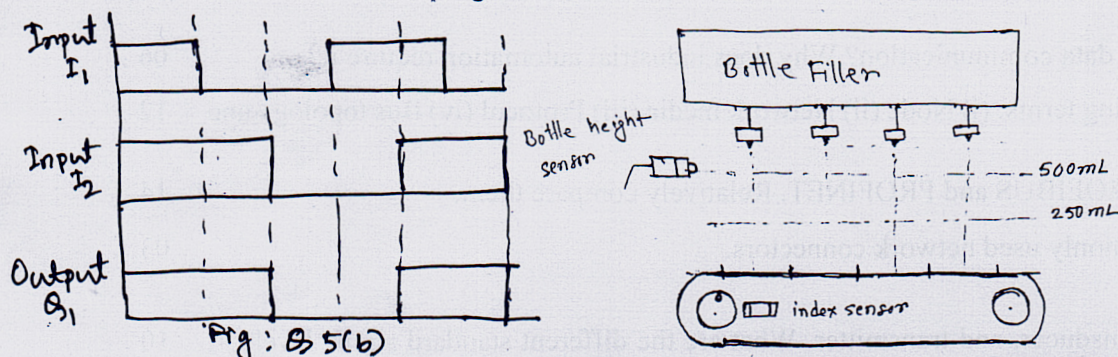
- 4(b) Draw a block diagram representation of the following continuous stirred tank blending process step by step with necessary approximations. The symbols denote the usual meaning. 16



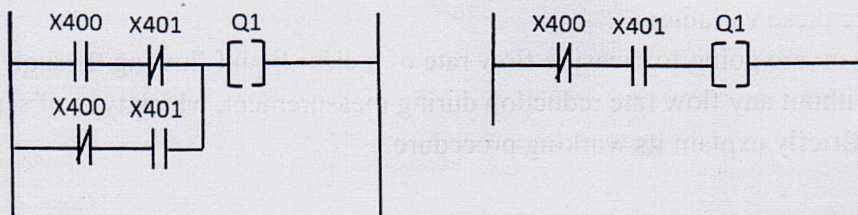
- 4(c) Define controller variable and manipulated variable. 05

SECTION-B

- 5(a) What is Ladder diagram? How is the scanning operation occurred in a Ladder diagram? 10
- 5(b) Draw the PLC ladder diagram from the following output. 08
- 5(c) What is sequential function chart? Describe the elements of a sequential function chart. 10
- 5(d) What is subroutines in Ladder diagram for PLC programming? Explain with example. 07
- 6(a) Write short notes on master control relay and battery-backed relays with necessary ladder diagram. 10
- 6(b) We have a bottle filter with six filling nozzles and this filter will be filling two different size bottles which are 250 mL and 500 mL for this filling task. We have to track the bottle size under each filling nozzle accurately. The bottle height sensor only can sense the height of 500 mL bottle. We have an index sensor in the conveyer which is activated once for every rotation of the gear. This sensor indicates the conveyer belt is moved one step forward. We can use the sensor signal as a trigger to shift the data bits across the shift register. We have six bottles of mixed size in the filter and we can track the location and the size of the bottles under each filling nozzle using shift registers. When all the six positions are placed by different size of bottles, then use timers to fill these bottles. Now draw a ladder program for this task. 15



- 6(c) Discuss data compression for PLC. Write down the instruction lists for the following Ladder programs shown below. 10



- 7(a) Write short notes on drum sequencer with necessary diagram. 10
- 7(b) Devise Ladder programs for a system that will carry out the following task: 12
- i. Give an output after a photocell sensor has given 10 pulse input signals as a result of detecting 10 objects passing in front of it.
 - ii. Give an output when the number of people in a store reaches 100, there continually being people entering and leaving the store.
- 7(c) Devise Ladder programs for a system that will carry out the following task: 13
- i. Switch on a pump when the water level in a tank rises above 1.2 m and switch it off when it falls below 1.0 m.
 - ii. Switch on a pump, then 100 s later ON a heater, then a further 30 s later switch on the circulating motor.
- 8(a) How can safety relays improve system safety and ensure prompt shutdown in case of failures? Explain with necessary circuit diagram. 10
- 8(b) Describe briefly the timing checks and last output set fault detection techniques. 10
- 8(c) Explain how using forcing, the failure of an input sensor or its wiring can be detected. 10
- 8(d) What are the steps in commissioning of a PLC system? 05

KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 4th Year 1st Term Examination, 2023

MTE 4103

(Digital Signal Processing and Machine Vision)

Time: 3.00 Hrs.

Total Marks: 210

- N.B.:** i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.

SECTION-A

- 1(a) What are the key merits and demerits of a FIR filter compared to an Op-amp 741 IC-based active filter? Which type of digital filter should be used for following two cases? 10
i) Sharp cut-off region and ii) Minimal phase distortion
- 1(b) Obtain at least six (6) coefficients of an FIR high-pass filter to meet the specifications given below using the Hamming window technique. 12
Passband edge frequency = 150 Hz
Transition width = 0.5 kHz
Stopband attenuation > 150 dB
Sampling frequency = 8 kHz
- 1(c) The step response of an LTI system is: 13
$$S(n) = \left(\frac{1}{3}\right)^{n-2} u(n+2)$$

(i) Find the transfer function $H(z)$ and sketch the pole-zero plot.
(ii) Determine the impulse response $h(n)$
(iii) Check if the system is causal and stable
- 2(a) Compute the convolution sum of following two signals using the “Circular Convolution” property of the DFT. 11
 $x_1(n) = \{1, 2, 0, \underset{\uparrow}{2}, 1\}$ and $x_2(n) = \{1, \underset{\uparrow}{2}, 0, 2, 1\}$
- 2(b) Differentiate between the following terms with necessary examples. 12
(i) Auto-correlation and Cross-correlation
(ii) Linear convolution and Circular convolution
- 2(c) Write down Parseval’s identity both in time domain and frequency domain. 05
- 2(d) Compute the energy and power of following discrete-time signal. 07
 $y[nT] = 3(-0.2)^n u(n-3)$; Here $T = 2$ ms
- 3(a) Determine the impulse response of the system characterized by the difference equation: 10
 $y(n) = 2.5y(n-1) - y(n-2) + x(n) - 5x(n-1) + 6x(n-2)$
- 3(b) State the relationship between DFT and z-transform. 05
- 3(c) Determine the causal signal $x(n)$ if its z-transform is given by: 10
i) $X(z) = \frac{1+2z^{-1}+z^{-2}}{1+4z^{-1}+4z^{-2}}$
ii) $X(z) = \frac{1+3z^{-1}}{1+3z^{-1}+2z^{-2}}$
- 3(d) Discuss the characteristics of practical frequency selective filters. 10
- 4(a) Derive the butterfly structure of radix-2 DIT FFT algorithm starting from the basic DFT equation. 11

- 4(b) Which properties of twiddle factor are exploited to reduce the computational complexity of DFT? Briefly explain the computational efficiency of FFT over DFT. 12
- 4(c) Given, $x(n) = \{1, 2, \underset{\uparrow}{3}, 2, 2, 3, 2, 4\}$. Find $X(k)$ using radix-2 DIT FFT algorithm. 12

SECTION-B

- 5(a) What is the fundamental difference between machine vision and computer vision? How do the application areas of machine vision and computer vision differ? Explain with necessary examples. 15
- 5(b) What are the components of machine vision system? Discuss about frame grabber as a component of machine vision system. 10
- 5(c) Discuss about the process of image sensing acquisition. Explain the fundamental working principle of CCD and CMOS image sensors. 10
- 6(a) What is the objective of image enhancement? Describe the method of histogram equalization. 10
- 6(b) Explain the difference between image enhancement and image restoration. Write down the name of some spatial domain image enhancement techniques. 10
- 6(c) Suppose that a 3-bit image ($L = 8$) of size 64×64 pixels has the gray level (intensity) distribution shown in table below: 15

r_k	n_k
$r_0 = 0$	790
$r_1 = 1$	1023
$r_2 = 2$	850
$r_3 = 3$	656
$r_4 = 4$	329
$r_5 = 5$	245
$r_6 = 6$	122
$r_7 = 7$	81

Perform histogram equalization on this image, and draw the histogram of equalized image.

- 7(a) What is the purpose of applying filters in image processing? What are the main types of filters used? 10
- 7(b) Consider the following 5×5 image. Apply a 3×3 median filter on the shaded pixels, and write the filtered image. 10

20	30	50	80	100
30	20	80	100	110
25	255	70	0	120
30	30	80	100	130
40	50	90	125	140

- 7(c) How the blurring of an image can be varied with the variation of mask size while using averaging linear filter? Support your answer with proper explanation. 10
- 7(d) What is the difference between image sharpening and image smoothing? 05
- 8(a) What is meant by image segmentation? What are the approaches for image segmentation? 10
- 8(b) What is the difference between gradient and Laplacian filter in digital image processing? 05

8(c) Apply Laplacian filter on the image given below. Write the filtered image.

10

8	5	4
0	6	2
1	3	7

8(d) Discuss the applications of object recognition in real-world scenarios. Compare traditional computer vision techniques with deep learning approaches in object recognition.

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KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 4th Year 1st Term Examination, 2023

MTE 4107

(Design of Mechatronic Systems)

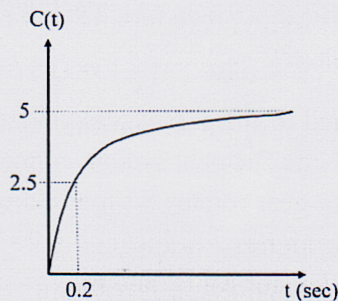
Time: 3.00 Hrs.

Total Marks: 210

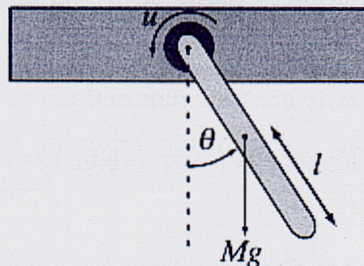
N.B.: i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.

SECTION-A

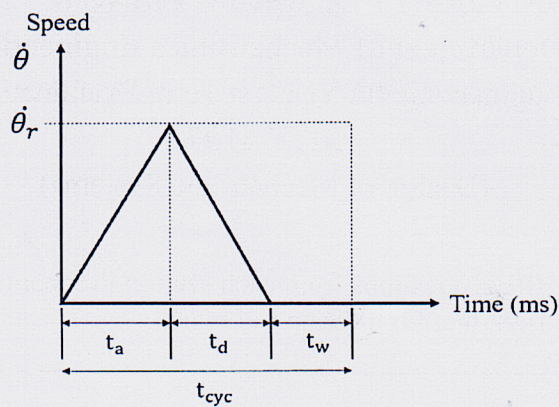
- 1(a) What is recognition of need? Why is it important in design? 05
- 1(b) What are the key elements of a mechatronic system? Give example of each of the elements. 08
- 1(c) How mechatronic system design approach is different from earlier design approach? Briefly explain. 12
- 1(d) Write short note on: (i) software in loop simulation and (ii) hardware in loop simulation. 10
- 2(a) Find out the mathematical model of a permanent magnet DC motor with load. The input is applied voltage, E_a and the output is the angular displacement of the rotor, θ_m . 18
- 2(b) Find the transfer function of the system showing the following response for unit step input. 12



- 2(c) What is modeling in system design? How can we get a mathematical model of a system? 05
- 3(a) Linearize the following simple pendulum system. u denotes an input torque provided by a DC motor. The other parameter holds regular meaning. 15



- 3(b) Write three major types of motion transmission. Write proper mechanism for each. 06
- 3(c) Consider a rotary motion axis driven by an electric servo motor. The rotary load is directly connected to the motor shaft without any gear. The rotary load is a solid cylindrical shape made of steel material $d = 100$ mm, $l = 25$ mm, $\rho = 4.6$ kg/m³. The desired motion profile is shown in the following figure. The total distance to be travelled is $\frac{1}{2}$ of the revolution. The period of the motion is $t_{cyc} = 150$ ms. The dwell portion of it is t_{dw} , acceleration and deceleration periods are t_a and t_d , respectively. Here, $t_a = t_d = t_{dw}$. Determine the required motor size for the application. 14



- 4(a) What is controller tuning? What are the purposes of using a controller? Name some of the controllers (control law) usually used. 10
- 4(b) Why Z-N step method for tuning is better than Z-N continuous cycling method? 10
- 4(c) Design a PID controller for a first order plus time delay (FOPTD) system using internal model control method. 15

SECTION-B

- 5(a) Why optimization is necessary in mechatronics system design? Explain with example. 10
- 5(b) Draw a flow chart of optimal design procedure. How design variables and constraints are selected in optimization problem? 13
- 5(c) An elevator system is designed to lift passengers using a motor-driven hoist. The motor generates a torque $T_m = 200 \text{ Nm}$. The gear system connected to the motor has a gear ratio of $r = 8:1$, meaning the output gear rotates 8 times slower than the input gear but with 8 times the torque. The hoist drum has a radius $r_d = 0.25 \text{ m}$. Calculate the required output torque, force exerted on the elevator cable, and maximum load mass. 12
- 6(a) What factors influence the friction coefficient of a robot's wheel? 05
- 6(b) How does the size of a wheel affect a robot's ability to climb over obstacles? 10
- 6(c) List and describe at least three features that contribute to a good drive system. 12
- 6(d) Why is it important to know what you want your machine to do before designing it? 08
- 7(a) What is a Kalman filter and why are they required in robotics? 05
- 7(b) How does the Kalman gain balance between prediction and measurement in the Kalman filter? 07
- 7(c) What is covariance matrix, and what does it represent in the context of a Kalman filter? 05
- 7(d) Describe how you would implement a Kalman filter for tracking a two wheeler LFR's position and orientation in 2D space with proper example. 18
- 8(a) How important is documentation in each stage of the mechatronics design process? 08
- 8(b) What are the main categories of data acquisition and control hardware? What challenges arise when there are large distances between instrumentation and sensors? 07
- 8(c) Describe the two methods for maintaining signal integrity over long distances in data acquisition systems. 10
- 8(d) Shortly describe the components of actuator system. Draw a comparison among stepper, servo and DC motor. 10