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) What is Machine Learning? Briefly discuss some practical applications of Machine Learning in Mechatronics Engineering.   10

1(b) Explain McCulloch-Pitts model of artificial neuron with appropriate sketch. Describe significance of its individual components.   05

1(c) Draw the minimal neural models for the following logics having inputs (X, Y, Z, and A).   10
    (i)   NN1 = (X + Z)′ A
    (ii)   NN2 = ((A & X′ & Z) | (A & Y′)) & ((X & Y) | (X & Z)′)

1(d) Explain the difficulties of solving XOR problem with single neuron. Solve XOR problem through manipulation by hidden neurons for AND and OR logic.   10

2(a) Consider the following optimization problem.   05
Minimize $f(x, y) = (x - 1)^2 + (y - 3)^2$
Subject to $x + y \leq 2$,
$x \geq y$
Write down the Lagrangian form for this problem.

2(b) Drive the dual Lagrangian objective function of soft SVM.   12

2(c) Consider the case of a binary class classification with a training data of 6 tuples as shown in the following table.   10

X_1	X_2	Y	α_i
0.38	0.48	+	1
0.49	0.71	-	1
0.82	0.31	-	0
0.75	0.90	-	1
0.19	0.59	+	0
0.41	0.35	-	0

The Lagrange multipliers α_i for each training tuple are solved using quadratic programming. Determine W and b to find out the Maximum Margin Hyperplane of linear SVM.

2(d) What is Kernel? Write down the Mercer's condition for kernel function. Explain three different types of kernel function.   08

3(a) Consider the following cost function and hypothesis for linear regression. Drive the normal equation, $\theta = (X^T X)^{-1} X^T Y$ to get the values of θ.   15
Given,
$$j(\theta) = \frac{1}{2m} \sum_{i=1}^{m} (h(\theta) - y)$$
$$h_\theta(e)^{(i)} = \theta_0 + \theta_1 X_1^{(i)} + \dots\dots + \theta_n X_n^{(i)}$$
How do you calculate θ when $(X^T X)$ is non-invertible?

3(b) What do you mean by Overfitting and underfitting? Write down a way to minimize both of the issues.   08

3(c) Write down the differences between Design matrix and Gradient descent optimization approach. 07

3(d) What are the common data types in machine learning? 05

4(a) Distinguish between supervised and unsupervised learning. 07

4(b) Derive the derivative of the logistic model. 08

4(c) What is likelihood function for logistic regression, and also find out the maximum log-likelihood estimator for logistic regression. 15

4(d) What are the advantages and disadvantages of using decision trees as a machine learning model? 05

SECTION-B

5(a) What is the difference between labeled data and unlabeled data? What do you mean by clustering? 07

5(b) Is the convergence of K-Means algorithm guaranteed? Support your answer with proper explanation. 08

5(c) Using K-Means clustering, cluster the following datasets for two clusters. 15

Sample No	Attribute 1	Attribute 2
01	185	72
02	170	56
03	168	60
04	179	68
05	182	72
06	188	77

5(d) What is the problem associated with the K-Means clustering algorithm? 05

6(a) What are the advantages of Hierarchical clustering over K-Means clustering? Write down the name of most commonly-used types of linkage for measuring similarity between clusters. 10

6(b) Suppose, you have a distance matrix from a dataset containing information about six customer's purchasing capability and age. Now, cluster these customers and draw the dendrogram using Hierarchical Agglomerative Clustering with single linkage method. The distance matrix is given below. 15

	B1	B2	B3	B4	B5	B6
B1	0					
B2	662	0				
B3	877	295	0			
B4	255	468	754	0		
B5	412	268	564	219	0	
B6	996	400	138	869	669	0

6(c) How do you find the optimal number of clusters to have upon looking at the dendrogram? 10
      Explain with a sketching of random dendrogram.

7(a) What is 'K' in the K Nearest Neighbor (KNN) algorithm and why is the odd value of 'K' 10
      preferred over even values in the KNN algorithm?

7(b) Apply K-Nearest Neighbor Algorithm for the following situation and find out the missing 15
      Y value. Use K = 1.

X1	X2	X3	Y
100	22.02	12	1
150	27.09	14	2
126	32.12	10	?

7(c) Briefly explain the curse of dimensionality problem. 10

8(a) Write short notes on: (i) Covariance. (ii) Correlation. Why is it necessary to compute a 10
      covariance matrix for Principle Component Analysis?

8(b) Consider the following dataset with 2 dimensions. 20

Dimension 1	Dimension 2
2.5	2.4
0.5	0.7
2.2	2.9
1.9	2.2
3.1	3.0
2.3	2.7
2.0	1.6
1.0	1.1
1.5	1.6
1.1	0.9

      Using Principle Component Analysis (PCA), reduce the dataset to one dimension.
      Explain each step with necessary calculations.

8(c) Briefly explain the two main approaches to dimensionally reduction: (i) Feature selection, 05
      (ii) Feature extraction.

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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 major components of an automobile? Explain the functions of ach of them.   13

1(b)   Explain the significance of Mechatronic systems in advanced vehicle technology with an example.   10

1(c)   Why valves are used in automobile engine? Draw the valve timing diagram of a four-stroke diesel engine.   12

2(a)   Differentiate between supercharger and turbocharger. Describe the working principle of electronic fuel injection system (EFI) with necessary figure.   12

2(b)   Why lubrication system is used in automobile? List the outstanding properties of an engine lubricating oil.   08

2(c)   State the purpose of the transmission of an automobile. Describe the operation of dog and spine clutch with necessary figure.   10

2(d)   Write short notes on service brakes and parking brakes.   05

3(a)   Describe the working of master cylinder used in braking system with necessary figure.   10

3(b)   What is the purpose of a synchronizer? Explain how a synchronizer works in a manual gear box.   10

3(c)   Define steering ratio. Write down the significance of it.   05

3(d)   State the purposes of shock absorber in suspension system. Also discuss the operation of shock absorber with necessary figure.   10

4(a)   Define the merits and demerits of radial tire over a bias ply tire.   10

4(b)   Write down the importance of tire grading. Describe the causes and remedies of excessive tire gear.   10

4(c)   What is steering system? Briefly explain on how it works.   10

4(d)   Write a short note on Parking Brake.   05

SECTION-B

5(a) What is meant by advanced vehicle technology? Explain the relationship of the term "Autotronics" with advanced vehicle technology. 10

5(b) Draw distinction between engine electronics and chassis electronics. Why air bags are considered as passive safety device? 10

5(c) What is the significance of using communication interfaces in electronic control unit (ECU)? Discuss about different types of communication interfaces used in ECUs. 15

6(a) Discuss about the operation of crankshaft position sensor as an input sensor in ECUs. 10

6(b) How does an antilock braking system (ABS) work? Does ABS eliminate the need for effective braking techniques? Support your answer with proper explanation. 10

6(c) Suppose you are an employee of Toyota. You are assigned to develop a cruise control system for a vehicle. Now design a feedback control system for achieving this task. Then explain how this developed system is working. 15

7(a) What is traction control system (TCS)? How does a TCS work? Is it only beneficial to drive on slippery surfaces? 10

7(b) Classify automotive safety devices with necessary examples. 08

7(c) Explain: - "Electronic stability program (ESP)" works in conjunction with ABS and TCS to enhance overall vehicle stability. 12

7(d) Why modern vehicles use ESP? 05

8(a) What is an electric vehicle (EV)? Outline the differences between an electric vehicle and a hybrid vehicle (HV). 10

8(b) What is meant by autonomous driving? Suppose, you have to develop a localization system for autonomous driving and you only have GPS and IMU. How will you accomplish this task? State the drawbacks of your developed localization system. 15

8(c) How do fuel cell vehicles work? And what sets them apart from traditional gasoline powered cars? 10

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KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY
Department of Mechatronics Engineering
B. Sc. Engineering 4th Year 1st Term Examination, 2022
MTE 4101
(Industrial Automation)
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) What are the key components and technologies that define Industrial 4.0 and how does Industrial 4.0 differ from conventional production?   10

1(b) Discuss the benefits and challenges associated with the implementation of Industrial 4.0 in industries. Provide examples to support your answer.   10

1(c) Discuss the potential impacts of Industrial 4.0 on the workforce and job market. What skills and competencies will be in demand in the era of advanced automation and smart factories?   10

1(d) Evaluate the role of human-machine collaboration in both conventional industrial production and Industrial 4.0.   05

2(a) What is industrial automation and how does it impact on the manufacturing industry? What are the key components of an industrial automation system?   12

2(b) Differentiate among fixed automation, programmable automation, and flexible automation.   11

2(c) What is meant by PLC? Draw a block diagram of a PLC showing the main functional components and explain the functions of each block.   12

3(a) What is DCS? How does DCS differ from SCADA system? Support your answer with appropriate example.   12

3(b) Briefly explain master to remote data transfer in SCADA system.   08

3(c) What are the key features and capabilities of a modern SCADA system.   07

3(c) What are the advantages of using a SCADA system compared to traditional manual control methods?   08

4(a) Describe PROFIBUS and Ethernet protocol for industrial communication.   10

4(b) Draw the PLC Ladder circuit from the following output.   10
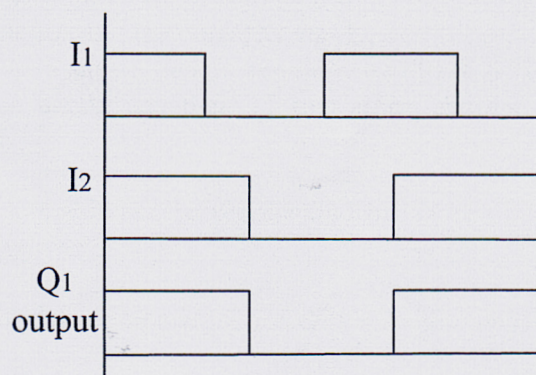
4(c)   What is the function of optoisolator in PLC?   0.

4(d)   Explain the operation of the following input and output devices: 10
        (i)   Magnetic read switch
        (ii)   Solenoid

SECTION-B

5(a)   What is Ladder diagram? How is the scanning operation occurred in a Ladder diagram?   10

5(b)   Draw the outputs for the following ladder diagrams shown in figure 5(b)?   10

(i)

(ii)
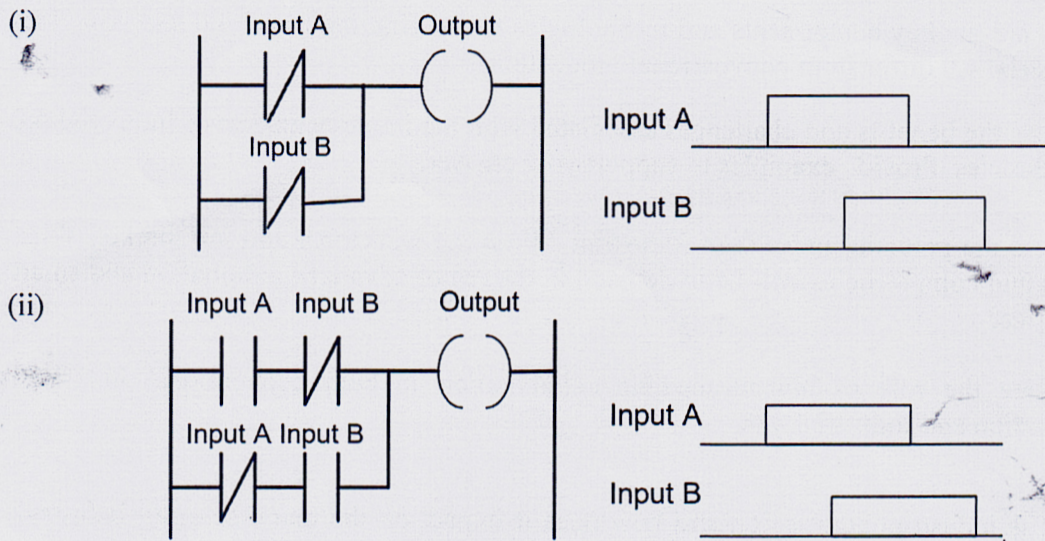
Figure 5(b)

5(c)   Draw the ladder diagram and functional block diagram to represent the followings: 15
        (i) $(A.B + C).\overline{D}.E.\overline{F} = Q$
        (ii)   A signal lamp is required to be switched on if a pump is running and the
               pressure is satisfactory, or if the lamp test switch is closed.
        (iii) Consider a system where there has to be no output when any one of four
               sensors gives an output; otherwise, there is to be an output.

6(a)   What is instruction list? Write down the instruction lists for the following ladder   12
       programs shown in Figure 6(a).

Figure 6(a)

6(b) What is sequential function chart? Draw the sequential function chart for the following   12
ladder diagram shown in Figure 6(b).

Figure 6(b)
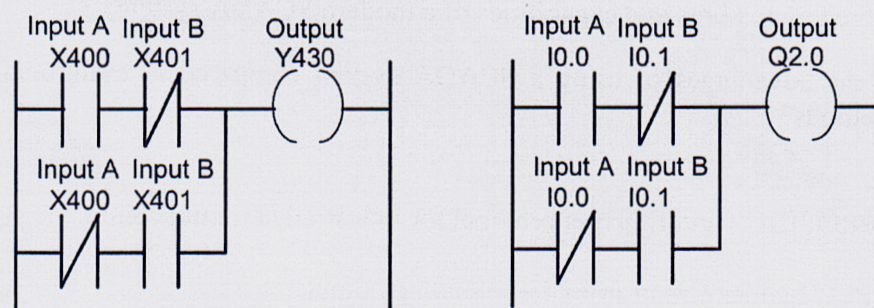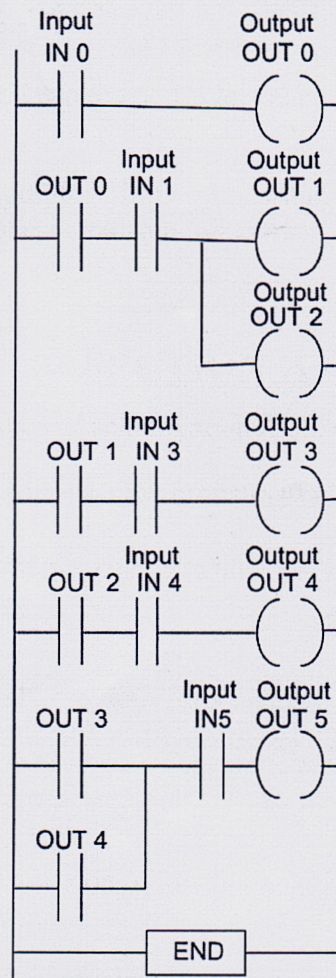
6(c) Write a PLC program to drive a motor in forward and in reverse direction. The motor   11
takes approximately 10 secs to down to its rest state. When switch S1 is pressed, coil-1
energizes making coil-2 de-energized.

7(a) Define internal relay. What is the function of battery-backed relay in PLC?   08

7(b) What is meant by subroutine in ladder diagram for PLC programing? Explain with   08
example.

7(c) Explain cascaded timer operation with example.   09

7(d) Draw a PLC ladder diagram for traffic light sequence control to give the sequence red   10
only, red plus amber, green, and amber, then repeat.

8(a) Devise ladder programs for systems that will carry out the following counting tasks.   12
    (i)   Items passing along a conveyor belt. The passage of an item past a particular
          point is registered by the interruption of a light beam to a photoelectric cell,
          and after a set number there is to be a signal sent informing that the set count
          has been reached and the conveyor stopped.
    (ii)   Control of a machine that is required to direct 6 tins along one path for
          packaging in a box and then 12 tins along another path for packaging in
          another box.

8(b) Define shift register. How this can be represented in ladder diagram? Explain with an   11
example of 4-bit shift register.

8(c) Discuss data movement, data comparison, and data selection process for PLC.   12

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KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY
Department of Mechatronics Engineering
B. Sc. Engineering 4th Year 1st Term Examination, 2022
MTE 4103
(Digital Signal Processing and Machine Vision)

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) What do you know by digital signal processing? What are the relative advantages and disadvantages of digital signal processing over analog signal processing.   10

1(b) What is meant by correlation? Determine the circular cross correlation values of the two sequences: 08
$X_1(n) = \{1, 2, 3, 4\}$ and $X_2(n) = \{4, 3, 2, 1\}$

1(c) Define DFT. State the relationship between DFT and Z-transform.   08

1(d) State Parseval's theorem. Determine the DFT of the sequence: 09

$$X(n) = \begin{cases} \dfrac{1}{5}, & for\ -1 \le n \le 1 \\ 0, & otherwise \end{cases}$$

2(a) What are the 'twiddle factors' of DFT? What properties of them are exploited to reduce the computational complexity of DFT? Briefly explain the computational efficiency of FFT over DFT.   10

2(b) Given, $X(n) = \{1, 2, 3, 4, 4, 3, 2, 1\}$. Find the $X(k)$ using DIT-FFT algorithm.   10

2(c) Compute the energy and power for the following discrete-time signal.   08
$$y(nT) = 2\,e^{j3n}\,u(nT);\quad T = 0.2\ sec$$

2(d) State Sampling theorem. Write down the differences between   07
   (i)   Static and dynamic system
   (ii) Casual and non-casual system

3(a) The transfer function of a digital system is: 11
$$H(z) = \frac{2}{1 - 0.4z^{-1}}$$
Do the following:
   (i)   Determine the difference equation of the system.
   (ii)   Find pole-zero plot and evaluate stability.
   (iii) Find and plot the impulse response.

3(b) Find the inverse z-transform of the output signal $Y(z)$, if input $x(n) = u(n-1)$ and impulse response $h(n) = (-0.25)^n\,u(n)$ 09

3(c) The impulse response of a linear time invariant system is given as $h(n) = \{1, 2, 3, 4\}$ and an arbitrary input signal $x(n) = \{1, 2, 3, 4\}$.   15
$\qquad\qquad\qquad\qquad\uparrow$
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\uparrow$
Determine the entire response of the system by using linear convolution technique.

4(a) What are the differences between FIR and IIR filters? What are the advantages of FIR filter over IIR filters?   08

4(b)   What is window technique of FIR filtering? A low-pass filter with passband gain of unity, cut-off frequency of 850 Hz and at a sampling frequency of F = 5000 Hz, the length of impulse response should be 5. Use Hanning Window to design this FIR digital filter.

4(c)   For the analog transfer function   10

$$H(z) = \frac{1}{(s+1)(s+2)}$$

Determine $H(z)$ using impulse invariant technique. Assume T = 1 s.

4(d)   A filter has following transfer function: 06

$$H(z) = \frac{1 + \frac{1}{4}z^{-1}}{(1 + \frac{1}{2}z^{-1})(1 + \frac{1}{2}z^{-1} + \frac{1}{4}z^{-2})}$$

Draw the realization form of $H(z)$.

SECTION-B

5(a)   What is the main objective of a machine vision system? Suppose you have got a job at Amazon and you have assigned to build a vision system to sort different size objects by a robot. Now, draw a schematic of a machine vision to sort different size objects by a robot and explain how will it work.   18

5(b)   What are the fundamental steps in digital image processing? Briefly explain each step with necessary diagram.   12

5(c)   What is meant by image interpolation.   05

6(a)   Define digital image. Drive the process of a digital image formation from a single sensor element as well as sensor strip.   10

6(b)   The continuum from image processing to computer vision can be broken into- low, medium, and high-level process. Now, explain these levels of process.   07

6(c)   Write down the advantages and disadvantages of digital image processing.   08

6(d)   Mention some applications of machine vision. State some future trends of machine vision. 10

7(a)   What are Salt and Pepper noises? Which filters are best to remove these noises?   06

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

Figure 7(b): Image

7(c)   What is image convolution and image correlation? Apply convolution operation on the image. Use 'Prewitt operator' as Kernel.   14

4	3	5
5	3	6
5	4	7

Figure 7(c): Image

7(d)   What is object recognition? How does deep learning work for machine vision? What is the difference between traditional machine vision and deep learning add-on vision system?   05

8(a)   What is the objective of image enhancement? Describe the method of histogram equalization.   10

8(b)   What is meant by edge detection of an image? How do you find the discontinuities in edge detection? State some usefulness of image segmentation with examples.   15

8(c)   Discuss the distinction between Linear Spatial Filtering and Nonlinear Spatial Filtering.   10

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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) What are the four questions that should be considered when designing a mechatronics system?   08

1(b) Compare between the classical design approach and concurrent design approach with proper block diagram.   10

1(c) What is real time simulation? Classify it. Briefly describe hardware in the loop simulation.   13

1(d) What is meant by optimization of a system?   04

2(a) Find out the generic block diagram representation of the following antenna azimuth position control system step by step. The input and output are shown in the figure. Also, reduce the block diagram.   16
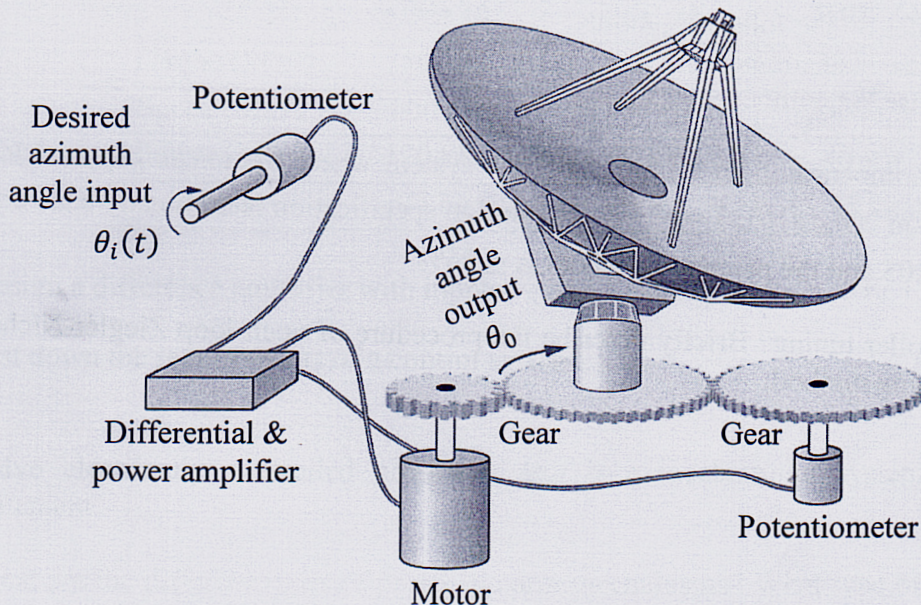
2(b) What is linearization? Why is it important?   05

2(c) Linearize the following magnetic suspension system at equilibrium point $y_{eq} = 3\ mm$. Express the new state-space representation. The symbols have their usual meanings.   14
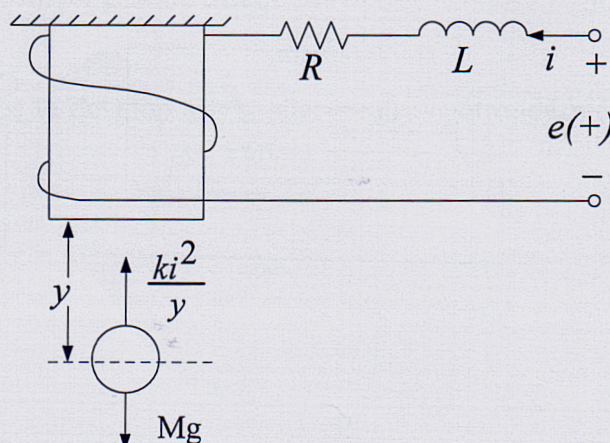
3(a) What is modeling of a process? What are the ways to obtain a mathematical model of a process? Briefly explain them.

3(b) What are the roles of motion transmission in mechatronic system? What are the three major types of motion transmission?

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 $d = 50\ mm$, $l = 25\ mm$, $\rho = 4.6\ kg/m^3$. The desired motion of the load is a periodic motion shown in the following motion profile. The total distance to be travelled is ¼ of the revolution. The period of the motion is $t_{cyc} = 250\ ms$, the dwell portion of it is $t_{dw} = 100\ ms$ and the remaining part of the cycle time is equally divided between acceleration, Constand speed, and deceleration periods, $t_a = t_r = t_d$. Determine the required motor size for this application.   16
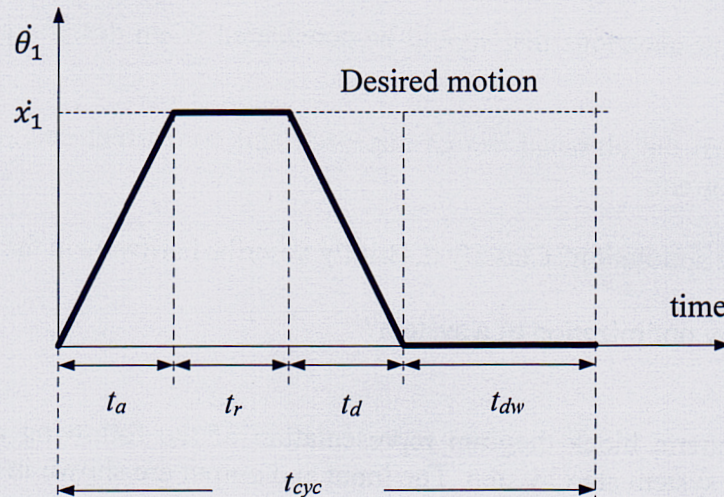

4(a) Write short notes on the following terms.   08
    (i)   Phase lead compensation
    (ii)   Phase lag compensation

4(b) Design a lag compensator for a unity feedback system where the uncompensated loop transfer function is $G_c(s)G(s) = \frac{k}{s(s+2)}$. The design specification is the steady-state error should be ≤ 0.05 and the percent overshoot is $\leq 25\%$.   15

4(c) What is controller tuning? Briefly describe the procedure of open-loop Ziegler-Nichols (Z-N) PID tuning method.   12

SECTION-B

5(a) Write a short note on Gain Scheduled and Model reference adaptive control.   10

5(b) Design the value of gain K for the feedback control system so that the system will respond with a 10% overshoot.   10
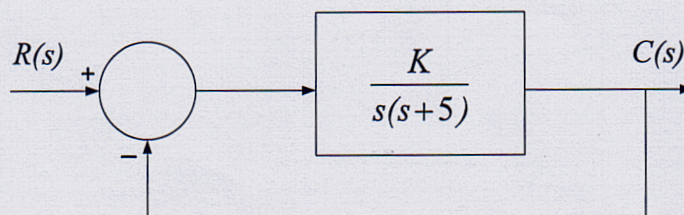
5(c) Generate a block diagram of the following electrical system and find $V_3(s)/V_1(s)$ from block diagram reduction.   15
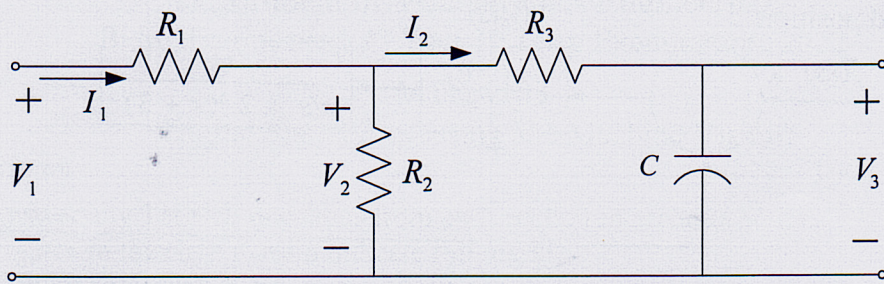
6(a) Select a suitable DC permanent magnet motor from the datasheet that satisfies the performance requirements stated below: 20

The total mass of the vehicle (live load and dead load) is 1300 kg. The electric vehicle must meet the following requirements:

Case I: On a level track
   Acceleration: it should be able to accelerate from 0 to 60 mph in 6 s.
   Top speed: It should be able to achieve a top speed of 100 mph.

Case II: Climbing at 30°
   Acceleration: It should be able to accelerate from 0 to 60 mph in 10 s.
   Top speed: It should be able to achieve a top speed of 75 mph.

Assume the following:

- An overall system efficiency of 88%.
- The vehicle is fitted with tires that have a diameter of 17 inches.

Table: Motor specifications

	HPD 40	HPD 35	HPD 30
Torque (Max)	750 Nm	500 Nm	350 Nm
Speed (Max)	2000 rpm	2000 rpm	2000 rpm
Power (Max)	120 kW	80 kW	40 kW
Mass	25 kg	21 kg	18 kg

6(b) Design a difference amplifier with inputs V_1 and V_2 such that $V_0 = -5V_1 + 3V_2$ 10

6(c) List down the requirements of a control system.   05

7(a) "Myo electrically controlled prosthetic arm is a mechatronic system." Justify the statement.   10
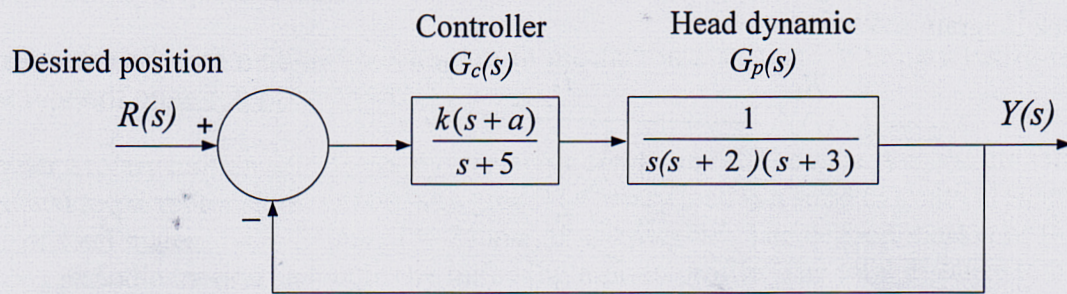
7(b) What are the different types of prosthetic arm mechanisms? What type of mechanism is deemed feasible to develop by you and why?   08

7(c) Briefly explain about signal conditioning required to process a signal from muscle sensor employed in prosthetic arm.   13

7(d) What potential advantages could be gained by using multiple sensors instead of a single sensor for individual finger gesture detection?   04

8(a) Write down the steps to develop a myo-electrically controlled prosthetic arm from the beginning.   10

8(b) A block diagram of a welding head position control is shown below. Find the values of k and a for which system is stable.

Controller $G_c(s)$

Head dynamic $G_p(s)$

Desired position

$R(s)$ +

$\dfrac{k(s+a)}{s+5}$

$\dfrac{1}{s(s+2)(s+3)}$

$Y(s)$

8(c) How can machine learning algorithm be applied in mechatronic systems for enhancing control and decision-making process?   10

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