**MEHRAN UNIVERSITY OF ENGG & TECHNOLOGY, JAMSHORO**

**DEPARTMENT OF ELECTRONIC ENGINEERING**

**LECTURE/LESSON PLAN**

**SUBJECT: CONTROL ENGINEERING-I**

**3rd YEAR 1st TERM**

**COURSE TUTOR: ENGR. IMTIAZ HUSSAIN KALWAR**

**As per Teaching plan:** **S.No#01** **Lecture No#01**

## Introduction To Control Systems

- Historical Review of Control systems.
- Basic Terms and Definitions (Controlled variable, Manipulated Variable, Plant, Process and Disturbance)
- Purpose of the Control System.
- Advantages and disadvantages of control System.
- Classification of Control Systems.
- Job of a Control Engineer

**As per Teaching plan:** **S.No#02** **Lecture No#02**

## Open Loop & Closed Loop Control Systems

- Definition of open loop and closed loop control systems.
- Introduction to open loop systems.
- Analysis of open loop system in terms of stability, sensitivity, accuracy, cost and complexity.
- Examples of open-loop Control Systems.
- Merits and Demerits of open-loop Control Systems.

**As per Teaching plan:** **S.No#02** **Lecture No#03**

## Open Loop & Closed Loop Control Systems

- Introduction to closed loop systems.
- Effect of feedback on the stability, overall gain, sensitivity, accuracy, bandwidth, cost and complexity.
- Examples of Closed loop control systems.
- Advantages and disadvantages of closed loop control systems.
- Comparison of open loop and closed loop control system.

**As per Teaching plan:** **S.No#03** **Lecture No#04**

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## Transfer Function, Poles and Zeros of a System, Stability

- Definition of Transfer function.
- Importance of transfer functions in the analysis of a control system.
- Finding poles and zeros from the transfer function.
- S-Plane (Complex plan)
- Plotting the poles and zeros in S-plane.
- Control system stability.
- Effect of location of poles on the stability of control system.
- Examples

**As per Teaching plan:** **S.No#04** **Lecture No#05**

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## Mathematical Modeling of Electrical Systems

- Introduction to mathematical modeling.
- Different types of mathematical models.
- Quick Review of Basic laws of circuit analysis (Ohm's Law, KVL. KCL).
- Quick Review of Nodal and Mesh analysis.
- Basic Components of a circuit (Resistor, Capacitor and Inductor) and their voltage & current relationships in time domain and in S-domain.
- Transfer Impedance, Driving point Impedance
- Formulation of Networks
- Transfer function of Networks
- Examples

**As per Teaching plan:** **S.No#05** **Lecture No#06**

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## Mathematical Modeling of Mechanical Systems

- Basic Components of Mechanical Translational Systems (Mass, Spring and Damper).
- Formulation of basic components using Newton's laws of motion.

- D'Alembert's Principle.
- Free body Diagram.
- Formulation of Mechanical translational network using D'Alembert's principle.
- Electrical analogy of mechanical translational networks.
- Transfer function of Mechanical translational networks
- Examples

**As per Teaching plan:** **S.No#05** **Lecture No#07**

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## Mathematical Modeling of Mechanical Systems

- Basic Components of Mechanical Rotational Systems (Inertia, Rotational Spring and Rotational Damper).
- Formulation of basic components using Newton's laws of motion.
- Free Body diagram.
- Formulation of Mechanical rotational network using D'Alembert's principle.
- Electrical analogy of mechanical Rotational networks.
- Transfer function of Mechanical rotational networks.
- Examples

**As per Teaching plan:** **S.No#05** **Lecture No#08**

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## Mathematical Modeling of Mechanical Systems

- Mechanical Linkages.
- Gear trains
- Importance of Gear trains in mechanical Systems.
- Mechanical coupling.
- Formulation of Gear trains.
- Generalized equation of Gear trains.
- Examples

**As per Teaching plan:** **S.No#06** **Lecture No#09**

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- Mathematical Modeling of Electro-Mechanical Systems
  - Modeling of Electrical Part.
  - Modeling of Mechanical part.
  - Combining Equation of Mechanical and Electrical parts.
  - Transfer function from the combined equations.
  - Example (Obtaining the Transfer function of Capacitor microphone and Moving Coil Voltmeter)

**As per Teaching plan:** **S.No#06** **Lecture No#10**

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- Mathematical Modeling of Electro-Mechanical Systems
  - Introduction to Armature controlled D.C motor.
  - Modeling of Armature controlled D.C Motor.
  - Modeling of Electrical part.
  - Modeling of Mechanical part.
  - Combining Equations
  - Transfer function

**As per Teaching plan:** **S.No#06** **Lecture No#11**

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- Mathematical Modeling of Electro-Mechanical Systems
  - Introduction to Field controlled D.C motor.
  - Modeling of Field controlled D.C Motor.
  - Modeling of Electrical part.
  - Modeling of Mechanical part.
  - Combining Equations
  - Transfer function

**As per Teaching plan:** **S.No#07** **Lecture No#12**

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- Block Diagram Representation of a Systems
  - Introduction to Block diagram representation.
  - Advantages and Disadvantages of Block diagram representation.
  - Block Diagram of open loop System
  - Block Diagram of Closed loop system.
  - Calculation of Error Ratio, Feedback Ratio and control Ratio.

**As per Teaching plan:** **S.No#07** **Lecture No#13**

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- Block Diagram Representation of a Systems
  - Example of Block Diagram (Calculation for Error Ratio, Feedback Ratio and Control Ratio).
  - Block Diagram Reduction Rules (Block in series, Block in parallel, Moving Take off point Beyond and ahead of a Block).
  - Examples

**As per Teaching plan:** **S.No#07** **Lecture No#14**

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- Block Diagram Representation of a Systems
  - Block Diagram Reduction Rules (Moving Summing point beyond and ahead of a Block).
  - Examples

**As per Teaching plan:** **S.No#08** **Lecture No#15**

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- Signal Flow Graphs
  - Introduction to Signal flow graph.
  - Advantages and Disadvantages of signal flow graphs.
  - Signal flow graph from mathematical model.

- Basic terms and definitions (loop, loop gain, non-touching loop, gain of non-touching loops, forward path and forward path gain)
- Example

**As per Teaching plan:** **S.No#08** **Lecture No#16**

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### Signal Flow Graphs

- Mason's gain formula
- Example

**As per Teaching plan:** **S.No#08** **Lecture No#17**

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### Signal Flow Graphs

- Signal Flow graph of Practical Systems
- Example (Armature Controlled D.C Motor, Field Controlled D.C Motor)

**As per Teaching plan:** **S.No#09** **Lecture No#18**

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### Standardized Inputs

- Step input (Definition, mathematical function and step Response)
- Impulse input (Definition, mathematical function and impulse Response)
- Ramp input (Definition, mathematical function and Ramp Response)
- Parabolic input (Definition, mathematical function and parabolic Response)

**As per Teaching plan:** **S.No#10** **Lecture No#19**

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### Transient Response

- Typical Step Response of a Control System
- Analysis of Step Response
- Transient Response parameters

**As per Teaching plan:** **S.No#11** **Lecture No#20**

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## Transient Response of First order System

- Step, impulse and ramp Response of a First order system
- Transient response specifications of first order system (Time constant, Gain )
- Calculation of parameters
- Examples

**As per Teaching plan:** **S.No#12** **Lecture No#21**

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## Transient Response of second order System

- Typical Step Response of a second order system
- Transient response specification (Damping ratio & Natural un-damped frequency)
- Transient response parameters of second order system (Rise time, Peak time, Maximum Overshoot, Settling time two percent and five percent criterion).
- Effect of Damping ratio and natural un-damped frequency on the step response of the system.

**As per Teaching plan:** **S.No#12** **Lecture No#22**

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## Transient Response of second order System

- Calculation of parameters
  - Rise time ($t_r$)
  - Peak time ($t_p$)
  - Maximum overshoot ($M_p$)
  - Settling time ($t_s$ for 2% and 5% criterion)
  - Effect of damping ratio and natural un-damped frequency on the transient response parameters.

**As per Teaching plan:** **S.No#12** **Lecture No#23**

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- Transient Response of second order System
  - Calculation of transient response specifications from transfer function
  - Calculation of transient response parameters from transfer function
  - Examples

**As per Teaching plan:** **S.No#12** **Lecture No#24**

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- Transient Response of second order System
  - Analysis of Second order systems based on transient response parameters
  - Design problems
  - Analysis of designed Systems

**As per Teaching plan:** **S.No#13** **Lecture No#25**

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- Steady Sate Errors
  - Definition of the steady state error
  - Effect of steady state error on the system response
  - Type number of the system
  - Effect of type number of the system on the steady state error
  - Final value theorem of Laplace Transform

**As per Teaching plan:** **S.No#13** **Lecture No#26**

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- Steady Sate Errors
  - Steady state error due to step input
    - Calculation of Positional Error constant ($K_p$)
    - Calculation of the positional error constant and steady state error of type-1, type-2 and type-3 systems.
  - Steady state error due to Ramp input

- Calculation of Velocity Error constant ($K_v$)
- Calculation of the velocity error constant and steady state error of type-1, type-2 and type-3 systems.

- Steady state error due to step Parabolic Input
  - Calculation of Acceleration Error constant ($K_a$)
  - Calculation of the acceleration error constant and steady state error of type-1, type-2 and type-3 systems.

**As per Teaching plan:** **S.No#13** **Lecture No#27**

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### Steady Sate Errors

- Comparison chart of error constants steady state errors of type-1, type-2 and type-3 systems due to step, ramp and parabolic inputs.
- Design problems

**As per Teaching plan:** **S.No#14** **Lecture No#28**

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### Sensitivity Function

- Definition of the sensitivity function
- Importance of the sensitivity function
- Calculation of the sensitivity Function
- Examples

**As per Teaching plan:** **S.No#15** **Lecture No#29**

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### Frequency Domain Analysis

- Introduction to frequency domain analysis
- Importance of frequency domain analysis
- Frequency domain parameters (Resonant Peak, Resonant Frequency, Bandwidth)
- Frequency Domain Techniques

**As per Teaching plan:** **S.No#16** **Lecture No#30**

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- Routh Herwitz Criterion
  - Absolute and relative stability of a control System
  - Methods of finding out absolute stability
  - Routh Herwitz criterion
  - Development of the Routh array
  - Finding Absolute stability from Routh array
  - Example

**As per Teaching plan:** **S.No#16** **Lecture No#31**

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- Routh Herwitz Criterion
  - Different cases of Routh Herwitz criterion
  - Information about location of poles from Routh array
  - Gain adjustment Using Routh Herwitz Criterion
  - Design problems
  - Examples

**As per Teaching plan:** **S.No#17** **Lecture No#32**

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- Bode Plots, Gain Margin & Phase Margin
  - Introduction to Bode Plot
  - Different features of Bode Plot
  - Different Cases
    - Magnitude & Phase plot of a constant
    - Magnitude & Phase plot of a Zero at origin
    - Magnitude & Phase plot of a pole at origin
  - Example

**As per Teaching plan:** **S.No#17** **Lecture No#33**

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- Bode Plots, Gain Margin & Phase Margin
  - Different Cases (Contd…..)
    - Magnitude & Phase plot Multiple zeros at origin
    - Magnitude & Phase plot of Multiple poles at origin
    - Magnitude & Phase plot of a zero in L.H.P
    - Magnitude & Phase Plot of a pole in L.H.P
  - Example

**As per Teaching plan:** **S.No#17** **Lecture No#34**

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- Bode Plots, Gain Margin & Phase Margin
  - Different Cases (Contd…..)
    - Magnitude & Phase plot Multiple zeros in L.H.P
    - Magnitude & Phase plot of Multiple poles in L.H.P
    - Magnitude & Phase plot of Complex zeros in L.H.P
    - Magnitude & Phase Plot of complex poles in L.H.P
  - Example

**As per Teaching plan:** **S.No#17** **Lecture No#35**

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- Bode Plots, Gain Margin & Phase Margin
  - Example involving various cases
  - Bode Plot on semi-logarithmic graph paper
  - Minimum-phase & Non-minimum-phase System
  - Bode plots for minimum phase systems
  - Gain cross-over & Phase cross-over points
  - Gain cross-over frequency & Phase cross-over frequency
  - Gain margin & Phase Margin
  - Example

**As per Teaching plan:** **S.No#18** **Lecture No#36**

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- Nyquist Stability Criterion, Gain Margin & Phase Margin
  - Introduction to the Nyquist Plot
  - Different features of Nyquist plot
  - Nyquist plot from typical transfer functions
  - Examples

**As per Teaching plan:** **S.No#18** **Lecture No#37**

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- Nyquist Stability Criterion, Gain Margin & Phase Margin
  - Gain Cross-over point & Phase cross-over point
  - Gain cross-over frequency & Phase cross-over Frequency
  - Gain margin and phase margin
  - Example

**As per Teaching plan:** **S.No#18** **Lecture No#38**

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- Nyquist Stability Criterion, Gain Margin & Phase Margin
  - General Nyquist Stability Criterion
  - Nyquist Stability criterion for minimum phase systems
  - Example

**As per Teaching plan:** **S.No#19** **Lecture No#39**

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- Nichol's Chart, Gain Margin & Phase Margin
  - Introduction to Nichol's chart
  - Nichol's chart of typical transfer functions
  - Constant Magnitude Loci (M-circles)
  - Constant Phase Loci (N-circles)

**As per Teaching plan:** **S.No#19** **Lecture No#40**

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- Nichol's Chart, Gain Margin & Phase Margin
  - Gain Cross-over and Phase Cross-over point
  - Gain Cross-over and Phase Cross-over frequencies
  - Gain Margin and Phase Margin
  - Gain Adjustment Using Nichol's Chart
  - Examples

**As per Teaching plan:** **S.No#20** **Lecture No#41**

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- Introduction to State-Space concepts & Terminology
  - Definitions
    - State
    - Space
    - State Space
    - State Variable
    - State Vector
  - Advantages of State Space Representation

**As per Teaching plan:** **S.No#21** **Lecture No#42**

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- Formation of State & Output Equations
  - State Space Representation from set of differential Equation
    - Selecting the suitable state variables
    - Relation among the state variables
    - Simulation Diagram or State Diagram
    - State equation
    - Output equation
    - System Matrix (A), Input Matrix (B), output Matrix (C) & Relational Matrix (D)
  - Example (State Space representation of Electric Network)

**As per Teaching plan:** **S.No#21** **Lecture No#43**

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- Formation of State & Output Equations
  - State Space Representation from Transfer Function
  - Direct Decomposition of Transfer function
  - Simulation Diagram
  - State Equation
  - Output Equation
  - Examples

**As per Teaching plan:** **S.No#21** **Lecture No#44**

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- Formation of State & Output Equations
  - State Space Representation from Transfer Function (Contd….)
  - Parallel Decomposition of Transfer function
  - Simulation Diagram
  - Examples

**As per Teaching plan:** **S.No#21** **Lecture No#45**

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- Formation of State & Output Equations
  - State Space Representation from Transfer Function (Contd….)
  - Cascade Decomposition of Transfer function
  - Simulation Diagram
  - Examples

**As per Teaching plan:** **S.No#22** **Lecture No#46**

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- Transfer Function Matrix
  - Computation of Transfer function Matrix
  - Examples

**As per Teaching plan:** **S.No#23** **Lecture No#47**

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- Eign Values & Eign Vector
  - Eign Values
  - Eign Vector
  - Calculation of Eign values
  - Examples

**As per Teaching plan:** **S.No#24** **Lecture No#48**

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- State Transition Matrix
  - State Transition Matrix or exponential Matrix
  - Computation of State Transition Matrix (Laplace Transform Method)
  - Properties of State Transition Matrix
  - Example

**As per Teaching plan:** **S.No#24** **Lecture No#49**

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- State Transition Matrix
  - Computation of state transition matrix (Series Summation Method)
  - Examples

**As per Teaching plan:** **S.No#25** **Lecture No#50**

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- Solution of State Equation
  - Solution of Homogenous state Equation
  - Examples

**As per Teaching plan:** **S.No#25** **Lecture No#51**

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- Solution of State Equation

- Solution of Non-Homogenous state Equation
- Examples

**As per Teaching plan:** **S.No#25** **Lecture No#52**

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## Solution of State Equation

- Time Response of a System
- Examples