Lesson Plan No. 1	Course Name: Control Systems Topic: Control systems	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. Understand the basic concepts and components of control systems. b. Differentiate between open-loop and closed-loop control systems. c. Apply control system principles to simple real-world problems. d. Understand the basic concept of sensor, actuators & controllers. e. Analyse the stability concept in time domain & frequency domain by various tools & techniques.
Teaching Aids (if any)	a. Small group activity sheets b. Diagrams and visual aids
Teaching Development	1. **Introduction** (5 minutes) - Ask questions. - Ask students to think of everyday examples of control systems - ask question of the components of a control system - ask question of the input a control system - ask question on the process/system a control system - ask question on the output a control system - ask question on the feedback a control system - ask question on the controller a control system - ask question on the open-loop systems of control system - ask question on the open-loop systems of control system - ask question on the closed-loop systems of control system 2. **Development** (30 minutes) Explore the concept of control systems - Take the daily life systems and explain them in the context of control system - explore the components of a control system - explore the Input i.e. desired value or set point. - explore the process/system: the mechanism or process being controlled. - explore the Output: The actual value or result of the process. - Explain the feedback systems - Explain the controller - Explore the open-loop systems of control system - Explain the closed-loop systems of control system - Analyse the difference between open-loop systems & closed loop systems Explain sensitivity & de-sensitivity of the system a. Evaluation of transfer function

	- Apply basic laws to the given control system. - Find the ratio of Laplace transform of output to the Laplace transform of input b. Introduce what a control system is—a system designed to regulate itself to maintain a desired output. 3. Exercise (5 minutes) – Give different use-cases and make students select appropriate different types of input - Step input or unit step input - Impulse input - Ramp input - Parabolic input
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework - Assign students a project to design a simple control system using any available resources Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 2	Course Name: Control Systems Topic: Mathematical modeling of physical systems	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. Understand the concept of mathematical modelling in the context of control systems. b. Derive transfer functions from given physical systems and vice versa. c. Apply differential equations to describe the behavior of physical systems. d. Solve differential equations to obtain analytical solutions for simple physical systems. e. Analyze real-life examples of physical systems and develop mathematical models using transfer functions and differential equations.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets
Teaching Development	1. **Introduction** (5 minutes) - Ask questions. - Discuss the mathematical modelling of physical systems in the context of control systems - explore the fundamental concepts and techniques used to represent the mathematical systems - need of mathematical modelling of the systems? - how factors like soil moisture, weather conditions, and plant growth interact with each other - where mathematical modelling comes into play - Discuss the characteristics and applications of open-loop and closed-loop systems. - mathematical models serve several crucial purposes - Transfer functions for mathematical system's input-output relationship - Different types of mathematical modelling - Highlight the need of mathematical modelling to understand the complex systems 2. **Development** (30 minutes) Explore the concept of mathematical modelling - Start the lesson with a brief discussion about the importance of mathematical modelling in control systems engineering - Introduce the basic concepts of mathematical modeling, including variables, parameters, relationships, and system

	dynamics. a. Differential Equation Model - Apply basic laws to the given control system. - Get the differential equation in terms of input and output by eliminating the intermediate variable(s). b. Modelling of Translational Mechanical Systems c. - Mass is the property of a body - kinetic energy - Moment of inertia - applied torque opposing torque due to moment of inertia angular acceleration angular displacement 3. Exercise (5 minutes) – Mathematical modelling of physical systems. - Determine the forces acting on the mass - Moment of Inertia - Apply Newton's Second Law - Student Academic Data (Hybrid Cloud) - Simplify the equations Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework - Modeling a Spring-Mass-Damper System - Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Google sheet quiz on Mathematical modelling of physical systems Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 4	Course Name: Control Systems Topic: block diagrams representation	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. Explain the basic components of a block diagram in a control system, summing junctions, and signals (inputs, outputs, disturbances). b. Demonstrate the ability to draw block diagrams for simple control systems involving feedback loops, cascaded control structures, and multi-input multi-output systems. c. Develop skills in analysing block diagrams to understand the overall system behaviour, including stability, steady-state error, transient response, and frequency response. d. Illustrate how different control strategies can be represented using block diagrams and analyse their effects on system performance. e. Apply block diagram techniques to design control systems that meet specified performance criteria for various engineering applications.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes) - Ask questions about importance of block diagrams in control systems. - Ask questions about the role block diagram in simplifying complex systems for analysis and design. - Define what is a block diagram. - explore the components (blocks, lines, summing junctions). - Discuss how the roots of the characteristic equation determine system stability. - explain the purpose of block diagrams in representing system structure, interconnections, and signal flow. - explore how block diagrams are used for system analysis, including stability analysis, transient response analysis, and frequency response analysis.

	2. **Development** (30 minutes) - explain the physical system or process being controlled, which may include mechanical, electrical, or chemical elements. - Explain the component responsible for generating control signals based on input signals and feedback from the system. a. - Define what a block diagram is and its components (blocks, lines, summing junctions). b. Discuss the purpose of block diagrams in representing system structure, interconnections, and signal flow. c. - Present examples of block diagrams in various engineering applications, emphasizing their versatility and utility. d. Components of Control System Block Diagrams - introduce the typical components found in control system block diagrams: plant, controller, sensors, actuators, and summing junctions. - Explain the function of each component and their roles in control system operation. - Illustrate how these components interact within a block diagram to regulate system behaviour. Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework - Create your video log highlighting block diagran concepts and submit on Google classroom. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on Block diagram Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 5	Course Name: Control Systems Topic: signal flow graphs	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the fundamentals of signal flow graphs and their applications in analysing control systems. b. Draw the signal flow graph of any complex model c. Apply signal flow graph techniques to evaluate the transfer function of any complex system. d. Illustrate the common analysis techniques used in signal flow graphs, such as Mason's gain formula and loop analysis.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes) - Ask questions about importance of signal flow graph in control systems. - Ask questions about the role signal flow graph in simplifying complex systems for analysis and design. - Explore signal flow graph. - Ask questions about key elements of signal flow graphs: nodes, branches, and gains - Ask questions how nodes represent system variables and branches represent connections between nodes - Ask questions how to construct a signal flow graph for a simple control system. - Explain how these techniques can be used to determine system transfer functions, evaluate stability, and analyze system performance. 2. **Development** (30 minutes) - Explain the graphical representations used in control systems to illustrate the flow of signals through the system components. - Explain the concept of signal flow graphs. a. - Define the key elements of signal flow graphs: nodes, branches, and gains.

	b. Discuss the purpose of signal flow graph in representing system structure, interconnections, and signal flow. c. -Explain examples of signal flow graph in various engineering applications, emphasizing their versatility and utility. d. Discuss strategies for simplifying complex signal flow graphs, such as reducing the number of nodes and branches. - Present common analysis techniques used with signal flow graphs, such as Mason's gain formula and loop analysis. - Explain how nodes represent system variables, branches represent connections between nodes, and gains represent the transfer functions associated with branches. - Discuss real-world applications of signal flow graphs in control systems engineering. Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework - Create your video log highlighting signal flow graph concepts and submit on Google classroom. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on signal flow graph. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 6	Course Name: Control Systems Topic: Time domain analysis of control systems	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the importance and objectives of time domain analysis in control systems. b. apply time domain techniques to analyse system behaviour and performance. c. Illustrate system stability, performance, and robustness. d. Illustrate the performance metrics such as rise time, settling time, overshoot, and steady-state error..
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes) - Ask questions about concept of time domain analysis in control systems. - Ask questions time domain analysis focuses on studying the response of a system to various input signals over time. - Ask questions on system's transient and steady-state response. - Ask questions about evaluating system stability, performance, and robustness. - Ask questions of time domain analysis for step response - Ask questions of time domain analysis for input impulse response - Ask questions of time domain analysis for input ramp response - Ask questions of time domain analysis for input parabolic response - Ask questions type and order of the systems - Ask questions on error and error constant of different types of systems

	2. **Development** (30 minutes) - Begin the lesson by introducing the concept of time domain analysis in control systems. - Explain the response of time domain, including transient response, steady-state response. a. – Explain the response due to different input signals. b. Explain the significance of key parameters such as rise time, settling time, overshoot, and steady-state error in evaluating system performance. c. –Explain the standard 2nd order equation d. – Evaluate the bandwidth, time content, damping factor and damping ration for the standard 2nd order equation e. Explain that time domain analysis involves studying the response of a system to input signals over time, focusing on transient and steady-state behaviour. - Demonstrate how to apply time domain analysis techniques to analyse and interpret system responses. - Discuss the insights gained from time domain analysis, such as system stability, transient response characteristics, and steady-state accuracy. Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework - Create your video log highlighting time domain analysis and submit on Google classroom. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on time domain analysis. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 7	Course Name: Control Systems Topic: time domain performance of first and second order control systems	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the time domain performance characteristics of first and second order control systems. b. understand the performance of first and second order control systems, including their transient and steady-state responses of first and second order control c. Illustrate system stability, performance, and robustness. d. Illustrate the performance metrics such as rise time, settling time, overshoot, and steady-state error..
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes) - Ask questions about concept of time domain analysis in control systems. - Ask questions time domain analysis focuses on studying the response of a system to various input signals over time. - Ask questions on system's transient and steady-state response. - Ask questions about evaluating system stability, performance, and robustness. - Ask questions of time domain analysis for step response - Ask questions of time domain analysis for input impulse response - Ask questions of time domain analysis for input ramp response - Ask questions of time domain analysis for input parabolic response - Ask questions type and order of the systems - Ask questions on error and error constant of different types of systems

	2. **Development** (30 minutes) - Begin the lesson by introducing the concept of time domain analysis in control systems. - Explain the response of time domain, including transient response, steady-state response. a. – Explain the response due to different input signals. b. Explain the significance of key parameters such as rise time, settling time, overshoot, and steady-state error in evaluating system performance. c. –Explain the standard 2nd order equation d. – Evaluate the bandwidth, time content, damping factor and damping ration for the standard 2nd order equation e. Explain that time domain analysis involves studying the response of a system to input signals over time, focusing on transient and steady-state behaviour. - Demonstrate how to apply time domain analysis techniques to analyse and interpret system responses. - Discuss the insights gained from time domain analysis, such as system stability, transient response characteristics, and steady-state accuracy. Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework - Create your video log highlighting time domain analysis and submit on Google classroom. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on time domain analysis. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 10	Course Name: Control Systems Topic: Stability characteristic equation	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. define stability in control systems. b. understand the concept of characteristic equations and their role in analyzing stability. c. Analyze stability of control systems by examining the roots of the characteristic equation. d. Apply stability analysis techniques, such as the Routh-Hurwitz criterion or the Nyquist criterion, to determine system stability based on characteristic equations. e. Analyse the system and predict stability on the basis of K.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes) - Ask questions about the characteristics equation. - Discuss the importance of stability for ensuring system reliability and performance. - Discuss how the roots of the characteristic equation determine system stability. - explore the fundamental concepts and techniques used to represent the stability analysis - Discuss how the roots of the characteristic equation determine system stability. - Work through examples of analysing stability using characteristic equations. - Discuss how the roots of the characteristic equation determine system stability. - Discuss the characteristics and applications of open-loop and closed-loop systems. - Introduce the concept of the characteristic polynomial and its significance. - Transfer functions for mathematical system's input-output relationship - Introduce the formal definition of cloud computing by NIST http://faculty.winthrop.edu/domanm/csci411/Handouts/NIST.pdf - Different types of mathematical modelling - Highlight the need of mathematical modelling to understand the

	complex systems 2. **Development** (30 minutes) Explain what characteristic equations are and their role in control system analysis. - Start the lesson with a brief discussion about the importance of mathematical modelling in control systems engineering - Show video of Facebook Data Center https://www.youtube.com/watch?v=_r97qdyQtIk - Introduce the basic concepts of mathematical modeling, including variables, parameters, relationships, and system dynamics. a. Differential Equation Model - Apply basic laws to the given control system. - Get the differential equation in terms of input and output by eliminating the intermediate variable(s). b. Modelling of Translational Mechanical Systems c. - Mass is the property of a body - kinetic energy - Moment of inertia - applied torque opposing torque due to moment of inertia angular acceleration angular displacement d. Advantages of Cloud Computing - Scale - Elasticity - On-demand/pay-per-use - Low cost of ownership - Higher RoI - Give examples to illustrate the advantages from a user-perspective. e. Challenges in Cloud Computing - Security - National Laws on Data Storage - Vendor Lock-in - Energy Efficiency (Give example of energy consumption in large data centers) - Resource Utilization 3. Exercise (5 minutes) – Give different use-cases and make students select appropriate cloud deployment models. - National Security Data (Private Cloud) - Health Data of Patients (Hybrid Cloud)

	- Credit card Details/Bank Details (Private Cloud) - Student Academic Data (Hybrid Cloud) - Learning Resources for Students (Public Cloud) Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Suggested Reading - Original NIST Paper on Cloud Computing http://faculty.winthrop.edu/domanm/csci411/Handouts/NIST.pdf 3. Homework - Create your video log highlighting cloud computing concepts and submit on Google classroom. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on Cloud Computing Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 11	Course Name: Control Systems Topic: stability of linear time invariant systems	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. define stability in control systems. b. understand the concept of characteristic equations and their role in analyzing stability. c. Analyze stability of control systems by examining the roots of the characteristic equation. d. Apply stability analysis techniques, such as the Routh-Hurwitz criterion or the Nyquist criterion, to determine system stability based on characteristic equations. e. Analyse the system and predict stability on the basis of K.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes) - Ask questions about the characteristics equation. - Discuss the importance of stability for ensuring system reliability and performance. - Discuss how the roots of the characteristic equation determine system stability. - explore the fundamental concepts and techniques used to represent the stability analysis - Discuss how the roots of the characteristic equation determine system stability. - Work through examples of analysing stability using characteristic equations. - Discuss how the roots of the characteristic equation determine system stability. - Discuss the characteristics and applications of open-loop and closed-loop systems. - Introduce the concept of the characteristic polynomial and its significance. - Transfer functions for mathematical system's input-output relationship - Introduce the formal definition of cloud computing by NIST http://faculty.winthrop.edu/domanm/csci411/Handouts/NIST.pdf - Different types of mathematical modelling

	- Highlight the need of mathematical modelling to understand the complex systems 2. **Development** (30 minutes) Explain what characteristic equations are and their role in control system analysis. - Start the lesson with a brief discussion about the importance of mathematical modelling in control systems engineering - Show video of Facebook Data Center https://www.youtube.com/watch?v=_r97qdyQtIk - Introduce the basic concepts of mathematical modeling, including variables, parameters, relationships, and system dynamics. a. Differential Equation Model - Apply basic laws to the given control system. - Get the differential equation in terms of input and output by eliminating the intermediate variable(s). b. Modelling of Translational Mechanical Systems c. - Mass is the property of a body - kinetic energy - Moment of inertia - applied torque opposing torque due to moment of inertia angular acceleration angular displacement d. Advantages of Cloud Computing - Scale - Elasticity - On-demand/pay-per-use - Low cost of ownership - Higher RoI - Give examples to illustrate the advantages from a user-perspective. e. Challenges in Cloud Computing - Security - National Laws on Data Storage - Vendor Lock-in - Energy Efficiency (Give example of energy consumption in large data centers) - Resource Utilization 3. Exercise (5 minutes) – Give different use-cases and make students select appropriate cloud deployment models. - National Security Data (Private Cloud)

	- Health Data of Patients (Hybrid Cloud) - Credit card Details/Bank Details (Private Cloud) - Student Academic Data (Hybrid Cloud) - Learning Resources for Students (Public Cloud) Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Suggested Reading - Original NIST Paper on Cloud Computing http://faculty.winthrop.edu/domanm/csci411/Handouts/NIST.pdf 3. Homework - Create your video log highlighting cloud computing concepts and submit on Google classroom. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on Cloud Computing Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 11	Course Name: Control Systems Topic: stability of linear time invariant systems	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the concept of stability in control systems. b. Learn about the stability criteria for linear time-invariant (LTI) systems. c. Analyze stability of control systems by examining the roots of the characteristic equation. d. Apply stability analysis techniques to evaluate system stability. e. Apply stability analysis techniques to evaluate system stability. f. Apply stability analysis techniques to evaluate system stability.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes) - Ask questions about stability analysis - Ask questions on absolute stability - Ask questions on conditional stability - Ask questions on marginal stability - equation. - Discuss the importance of stability for ensuring system reliability and performance. - Discuss how the roots of the characteristic equation determine system stability. - explore the fundamental concepts and techniques used to represent the stability analysis - Discuss how the roots of the characteristic equation determine system stability. - Work through examples of analysing stability using characteristic equations. - Discuss how the roots of the characteristic equation determine system stability. - Discuss the characteristics and applications of open-loop and closed-loop systems. - Introduce the concept of the characteristic polynomial and its

	significance. - Transfer functions for mathematical system's input-output relationship - Introduce the formal definition of cloud computing by NIST http://faculty.winthrop.edu/domanm/csci411/Handouts/NIST.pdf - Different types of mathematical modelling - Highlight the need of mathematical modelling to understand the complex systems 2. **Development** (30 minutes) Define stability in the context of control systems. Discuss the importance of stability for ensuring system performance and safety. Explain the stability criteria for LTI systems - Show video of Facebook Data Center https://www.youtube.com/watch?v=_r97qdyQtIk - Introduce the basic concepts of mathematical modeling, including variables, parameters, relationships, and system dynamics. a. Routh-Hurwitz Stability Criterion - Present the Routh-Hurwitz stability criterion in detail.. - Demonstrate how to construct the Routh array and determine system stability using this criterion. Work through example problems to illustrate the application of the criterion. b. Nyquist Stability Criterion - Introduce the Nyquist stability criterion. - Explain the concept of the Nyquist plot and its relationship to system stability. - Guide students through plotting Nyquist diagrams and interpreting stability from them. - Guide students through plotting Nyquist diagrams and interpreting stability from them. - Guide students through plotting Nyquist diagrams and interpreting stability from them. c - Bode Stability Criterion - Discuss the Bode stability criterion and its advantages. - Explain how to use Bode plots to assess system stability. - Conduct examples of analyzing stability using Bode plots. c. Advantages stability of linear time invariant systems - Stable LTI systems exhibit predictable behavior over time. - Predictable Behavio

	- Robustness: - Ease of Analysis - Feedback Control d. Challenges in stability of linear time invariant systems - Complexity of Systems -Nonlinearities -Uncertain Parameters: -Pole-Zero Configurations -Interaction with External Disturbances -Design Trade-offs 3. Exercise (5 minutes) – Give different use-cases and make students select appropriate stability of linear time invariant systems. - Number of roots lies on right half of s-plane - Number of roots lies on left half of s-plane - Hurwitz determinant - Stability condition of Hurwitz determinant - Construction of Hurwitz determinant - Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Suggested Reading - Original NIST Paper on Cloud Computing http://faculty.winthrop.edu/domanm/csci411/Handouts/NIST.pdf 3. Homework - Create your video log highlighting cloud computing concepts and submit on Google classroom. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on Cloud Computing Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 13	Course Name: Control Systems Topic: Stability characteristic equation	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. define stability in control systems. b. understand the concept of characteristic equations and their role in analyzing stability. c. Analyze stability of control systems by examining the roots of the characteristic equation. d. Apply stability analysis techniques, such as the Routh-Hurwitz criterion or the Nyquist criterion, to determine system stability based on characteristic equations. e. Analyse the system and predict stability on the basis of K.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes) - Ask questions about the characteristics equation. - Discuss the importance of stability for ensuring system reliability and performance. - Discuss how the roots of the characteristic equation determine system stability. - explore the fundamental concepts and techniques used to represent the stability analysis - Discuss how the roots of the characteristic equation determine system stability. - Work through examples of analysing stability using characteristic equations. - Discuss how the roots of the characteristic equation determine system stability. - Discuss the characteristics and applications of open-loop and closed-loop systems. - Introduce the concept of the characteristic polynomial and its significance. - Transfer functions for mathematical system's input-output relationship - Different types of mathematical modelling - Highlight the need of mathematical modelling to understand the complex systems

	2. **Development** (30 minutes) Explain what characteristic equations are and their role in control system analysis. - Start the lesson with a brief discussion about the importance of mathematical modelling in control systems engineering - Introduce the basic concepts of mathematical modeling, including variables, parameters, relationships, and system dynamics. a. Differential Equation Model - Apply basic laws to the given control system. - Get the differential equation in terms of input and output by eliminating the intermediate variable(s). b. Modelling of Translational Mechanical Systems c. - Mass is the property of a body - kinetic energy - Moment of inertia - applied torque opposing torque due to moment of inertia angular acceleration angular displacement Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on Cloud Computing Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 14	Course Name: Control Systems Topic: stability of linear time invariant systems	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand significance of stability in control system b. analyse the difference between stable and unstable systems c. analyse stability using various methods applicable to linear time-invariant systems. d. Apply stability analysis techniques using Routh-Hurwitz criterion, bode plot & Nyquist criterion, to determine system stability based on characteristic equations. e. Illustrate the stability concept by varying the k and determine the stable, marginal stable & unstable systems.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes) - Ask questions about the transfer function. - Ask questions about the characteristic equation. - Ask questions about the Routh array. - Ask questions about the first column of the Routh array. - Ask questions about the numbers of pole lies on right half of s-plane or left half of s-plane. - Check the how many poles lies on right half of s-plane 2. **Development** (30 minutes) - Explain the transfer function - deduce the characteristics equation from the transfer function - Explain the Routh array for characteristics equation - Explain the Routh coefficients & construct the Routh table - Present the Routh-Hurwitz criterion as a method to determine - stability using the system's characteristic equation. - Explain the first column of the Routh array - Explain the number of signed changed in the first column of the Routh array - Explain the number of signed changed to check the stability of the systems

	- If any complete row is negative then make it positive by taking negative sign common - if first column of any row is zero then it is replaced by p keeping the limit of p tending to zero & then checked the signed changed for the stability Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on stability of linear time invariant systems Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 15	Course Name: Control Systems Topic: Routh-Hurwitz Criterion	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the concept of stability in control systems by using Routh-Hurwitz criterion b. Articulate the concept of stability by changing the parameter gain K c. Illustrate the Routh table and by solving the table predict the stability d. Understand the importance of sign changed easily predict the stability
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes). - Ask questions about the characteristic equation. - Ask questions about the Routh array. - Ask questions about the Routh array coefficients. - Ask questions about the computation of the Routh array coefficients - Ask questions about the concept of sign changed - Ask questions about the numbers of pole lies on right half of s-plane or left half of s-plane. - Check the how many poles lies on right half of s-plane - Ask questions about the prediction of stability using Routh Array 2. **Development** (30 minutes) - Explain the transfer function - deduce the characteristics equation from the transfer function - Explain the Routh array for characteristics equation - Explain the Routh coefficients & construct the Routh table - stability using the system's characteristic equation. - Explain the first column of the Routh array - Explain the number of signed changed in the first column of the Routh array - Explain the number of signed changed to check the stability of

	the systems - If any complete row is negative then make it positive by taking negative sign common - if first column of any row is zero then it is replaced by p keeping the limit of p tending to zero & then checked the signed changed for the stability **3. Exercise** Ask students to explain each Routh tble. Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework on Routh-Hurwitz Criterion Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on stability of Routh-Hurwitz Criterion 3. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 17	Course Name: Control Systems Topic: Root locus plot	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the concept of frequency domain analysis b. understand the concept of stability analysis by using Frequency domain analysis c. Articulate the concept of various parameters for determination of stability d. Apply the techniques such as Bode plot, root locus, polar plot & Nyquist plot to prdict the stability
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes). - Ask questions about the characteristic equation. - Ask questions about the pole-zero plot. - Ask questions 2^{nd} degree equation - Ask questions time constant, bandwidth, natural frequency & resonant frequency 2. **Development** (30 minutes) - Explain the characteristic equation. - deduce the characteristics equation from the transfer function - Explain the pole-zero plot. - Explain the 2^{nd} degree equation - Explain the time constant, bandwidth, natural frequency & resonant frequency **3. Exercise** Ask students to explain frequency domain analysis Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework on frequency domain analysis Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on stability of frequency domain analysis 3. Spend 5 minutes to evaluate student assimilation of the lesson

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Lesson Plan No. 17	Course Name: Control Systems Topic: Root locus plot	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the concept of root locus b. understand the method to draw the root locus c. Identify the branch of root locus from the plotted pole-zero in S-plane d. Analyse the root locus for any given transfer function
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes). - Ask questions about the concept of root locus. - Ask questions about the rule to draw root locus. - Ask questions about branch of root locus from the plotted pole-zero in S-plane - Ask questions for pole-zero plot 2. **Development** (30 minutes) - Explain the concept of root locus. - deduce the pole-zero plot - Explain the technique involved in root locus. - Explain the branch of root locus **3. Exercise** Ask students to branch of root locus Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework on root locus analysis Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on techniques to draw the root locus 3. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 18	Course Name: Control Systems Topic: Analysis of Root locus plot	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the branch of root locus and counter root locus b. understand the concept of parameter gain K c. Identify the breakaway & break-in point d. Analyse the root locus for any given transfer function
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes). - Ask questions about the concept of root locus. - Ask questions about the rule to draw root locus. - Ask questions about branch of root locus from the plotted pole-zero in S-plane - Ask questions for pole-zero plot 2. **Development** (30 minutes) - Explain the concept of root locus. - deduce the pole-zero plot - Explain the technique involved in root locus. - Explain the branch of root locus **3. Exercise** Ask students to branch of root locus Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework on root locus analysis Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on techniques to draw the root locus 3. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 19	Course Name: Control Systems Topic: Bode plot	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the concept of corner frequency b. understand the asymptotic plot, log magnitude plot c. analyse the error at the asymptotic point
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes). - Ask questions corner frequency. - Ask questions asymptotic plot, log magnitude plot. - Ask questions about asymptotic plot, log magnitude plot - Ask questions about the plot gain in decibel versus frequency - Ask questions about the plot phase in degree versus frequency 2. **Development** (30 minutes) - Explain the concept of corner frequency. -Explore asymptotic plot, log magnitude plot. - Explain the plot gain in decibel versus frequency. - Explain the plot phase in degree versus frequency - Explain the difference between decade frequency & octave frequency **3. Exercise** Ask students to error analysis in the asymptotic plot Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework on Bode plot analysiss analysis Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on techniques to transfer function for the bode plot 3. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 20	Course Name: Control Systems Topic: Bode plot technique	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the corner frequency for the given transfer function b. understand the initial slope & its characteristics (0 db, 20db & -20 db) c. analyse the gain constant & its impact on the initial slope of bode plot d. articulate the concept of gain cross over frequency & phase cross over frequency e. Illustrate the concept of gain margin & phase margin in frequency domain analysis
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes). - Ask questions corner frequency for the given transfer function. - Ask questions the initial slope & its characteristics (0 db, 20db & -20 db) - Ask questions about the gain constant & its impact on the initial slope of bode plot - Ask questions the concept of gain cross over frequency & phase cross over frequency - Ask questions about concept of gain margin & phase margin in frequency domain analysis 2. **Development** (30 minutes) - Explain the corner frequency for the given transfer function. -Explore the initial slope & its characteristics (0 db, 20db & -20 db) - Explain the gain constant & its impact on the initial slope of bode plot - Explain the concept of gain cross over frequency & phase cross over frequency - Explain the concept of gain margin & phase margin in frequency domain analysis **3. Exercise** Ask students to evaluation the transfer function for the bode plot

	Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework on evaluation transfer function using Bode plot 3. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on techniques to transfer function for the bode plot 3. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 21	Course Name: Control Systems Topic: Polar plot technique	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the concept of polar plots b. understand the interpretation of frequency response characteristics using polar plots, and practice creating polar plots for various systems c. analyse the plot of gain & phase versus frequency, and draw the plot d. polar plots as graphical representations of the frequency response of a system in polar coordinates.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes). - Ask questions on graphical representations of the frequency response of a system in polar coordinates. - Ask questions on the concept of polar plots - Ask questions about plot of gain & phase versus frequency, and draw the plot - Ask questions the concept of gain cross over frequency & phase cross over frequency - Ask questions the interpretation of frequency response characteristics using polar plots, and practice creating polar plots for various systems 2. **Development** (30 minutes) - Explain concept of polar plots. -Explore the interpretation of frequency response characteristics using polar plots, and practice creating polar plots for various systems - Explain plot of gain & phase versus frequency, and draw the plot - Explain the concept of gain cross over frequency & phase cross over frequency - Explain the concept of gain margin & phase margin in frequency domain analysis **3. Exercise**

	Ask students to evaluation the transfer function for the bode plot Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework on evaluation of polar plot 3. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on techniques of polar plot 3. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 22	Course Name: Control Systems Topic: Nyquest Criterion	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the Nyquist Criterion in Control Systems b. Understand how to interpret Nyquist plots. c. Apply the Nyquist Criterion to analyse stability in control systems.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes). - Ask questions on Nyquist Criterion in Control Systems - Ask questions on to draw the Nyquist plot with the help of polar plot - Ask questions to plot the graph of the polar plot - Ask questions to evaluate the phase of various types of transfer function - Ask questions to evaluate the magnitude of various types of transfer function - Ask questions about the contour of the transfer function 2. **Development** (30 minutes) - Explain phase versus frequency plot of the Nyquist plot. - Explain magnitude versus frequency plot of the Nyquist plot. - plot the graph of the polar plot - Explain evaluation of the phase of various types of transfer function - Explain evaluation of the magnitude the of various types of transfer function **3. Exercise** Ask students to evaluation the transfer function for the bode plot Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework on evaluation of Nyquist criterion 3. Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to

	answer and discuss. 2. Nearpod Quiz on techniques of Nyquist criterion 3. Spend 5 minutes to evaluate student assimilation of the lesson contents

Lesson Plan No. 23	Course Name: Control Systems Topic: phase lead and phase lag compensator	Course No.: ECE-604

Objectives	At the end of the lesson the student shall be able to: a. understand the phase lead and phase lag compensator b. Analyze the effects of phase lead and phase lag compensators on system stability and performance c. Understand the compensators are designed to alter the phase and magnitude characteristics of a system to meet certain performance criteria.
Teaching Aids (if any)	a. Projector or slides for presentations b. Small group activity sheets c. Diagrams and visual aids d. Real-world examples (videos, images, or physical examples)
Teaching Development	1. **Introduction** (5 minutes). - Ask questions on Lead compensator - Ask questions on Lag compensator - Ask questions on Lead-lag compensator - Ask questions on lag-lead compensator - - Ask questions of the purpose of phase lead compensator in control systems. - Ask questions of the purpose of lag lead compensator in control systems. - Ask questions how phase lead compensator increases the phase margin and improves system stability. 2. **Development** (30 minutes) - Explain lead compensators - Explain the lag compensator - Explain the lag-lead compensator - Explain the lead-lag compensator - Explain the purpose of phase lead compensator in control systems. - Explain how phase lead compensator increases the phase margin and improves system stability. **3. Exercise**

	Ask students to evaluation the transfer function for the bode plot Use Nearpod to collect responses and discuss the answers.
Closure	1. Summarize the Lesson Learning Outcomes and get affirmation from students on these. 2. Homework on evaluation of phase lead and phase lag compensator Spend 5 minutes to wrap up and consolidate the learnings
Evaluation	1. Reflective Questions (What, Why, Who?). Allow students to answer and discuss. 2. Nearpod Quiz on techniques of phase lead and phase lag compensator 3. Spend 5 minutes to evaluate student assimilation of the lesson contents