Course Code: PC-EI501	**Category:** Professional Core Courses
Course Name: Control System	**Semester: 5**
L-T-P: 3-0-0	**Credit: 3**
Total Lectures: 46	
Pre-Requisite: Engineering mathematics that teaches complex variables and Laplace transform.	

Objectives:

1. To understand the use of transfer function models for analysis of physical systems. and introduce the control system components.
2. To provide adequate knowledge in the time response of systems and steady state error analysis.
3. To accord basic knowledge in obtaining the open lop and closed–lop frequency responses of systems.
4. To introduce state variable representation of physical systems.
5. To introduce stability analysis and design of compensators.

Module No.	Description of Topics	Contact Hrs
1.	**Introduction and overview:** Define the Control problem with examples. Meaning of reference input, Control input, disturbance input and controlled output.	2
2.	**Modeling:** Define Linear Time variant system. Modeling problem for linear time invariant system. Impulse response and convolution integral for LTI system. Transfer function modeling of systems: Input output relation in Laplace domain and Transfer function; Block Diagram reduction, signal flow graph, Mason's Gain theorem. Representation of system and reduction to their transfer function. Modeling of some physical system--- Electrical circuit, Mechanical motors, thermal (room temperature), pneumatic etc. Concepts of States, State space modeling, Solution of state equations, State space to transfer function, transfer function to state space (realization problem). Examples of state space modeling---- Coupled tank system, inverted pendulum, biological system etc	10
3.	**Characterization of Plant:**	10

	Definition of stability. Criteria for stability of a system. Pole-zero concept, Routh-Hurwitz Criterion, Eigen value. Equivalence of pole and Eigen value. Time domain: Standard test signals. Time response of first and second order systems for standard test inputs. Application of initial and final value theorem. Design specifications for second-order systems based on the time-response. Frequency-domain: Meaning of frequency response, Analytical evaluation of Frequency response of given transfer function. Polar plots, Bode plots and Nyquist plot for representation of frequency response. Gain cross over frequency, phase cross over frequency. Role off rate. DC gain, corner frequency.	
4.	**Characterization of feedback loop:** Advantages of feedback**.** Loop Stability: Bode and Nyquist plot criteria. Bode stability criteria Nyquist stability criteria, loop robustness, gain margin, phase margin, delay margin. Loop performance: Frequency domain parameter sensitivity, tracking, disturbance rejection. Loop performance in time domain: Transient response: Root locus, Steady state response: Steady state error.	9
5.	**Controller Design problem:** PID Control. Frequency domain Loop shaping approach: Lead, Lag, Lag-lead compensator. Model matching approach: Two degree of freedom controller. State feedback approach: Controllability, Observability, Pole placement, State Observer.	8
6.	**Introduction to Optimal Control and Nonlinear Control:** Nonlinear Control: Linearization about operating points. Optical Control: Performance Indices and their optimization. LQR problem.	7

Course Outcomes: At the end of this course, students will understand

1. The modeling of linear-time-invariant systems using transfer function and state-space representations.
2. The concept of stability and its assessment for linear-time invariant systems.
3. Characterization of plants and control loops.

4. The need for compensation, & the methods used for compensation techniques.
5. Linearization of non-linear system
6. Performance indices for optimal control.

Text/References:

1. Automatic Control System: Basic analysis and design by William A. Wolovich, The Oxford Series in Electrical and Computer Engineering.
2. B. C. Kuo, “Automatic Control System”, 10^{th} Mc Graw Hill.
3. K. Ogata, “Modern Control Engineering”, Prentice Hall, 5^{th} edition.
4. I. J. Nagrath and M. Gopal, “Control Systems Engineering”, New Age International, 2009
5. Control Systems Engineering, 6^{th} edition, ISV (WSE), by Norman Nise, Wiley
6. Control Systems, Ambikapathy, Khanna Publishing House, 2018.
7. Control Systems, N K Sinha, New Age International Pvt, 2013.