Paper code: ARI 208	L	T/P	Credits
Subject: Control Systems	4	-	4

Marking Scheme:

Teachers Continuous Evaluation: As per university examination norms from time to time.

End Term Theory Examination: As per university examination norms from time to time.

INSTRUCTIONS TO PAPER SETTERS: Maximum Marks: As per University Norms

- There should be 9 questions in the end-term examination question paper.
- Question No. 1 should be compulsory and cover the entire syllabus. This question should have objective or short answer type questions. It should be 15 marks.
- Apart from Question No. 1, the rest of the paper shall consist of four units as per the syllabus. Every unit should have two questions. However, students may be asked to attempt only 1 question from each unit. Each question should be 15 marks.
- The questions are to be framed keeping in view the learning outcomes of the course/paper. The standard/ level of the questions to be asked should be at the level of the prescribed textbooks.
- The requirement of (scientific) calculators/log tables/data tables may be specified if required.

Course Outcomes [Bloom's Knowledge Level (KL)]:

CO1	Ability of students to utilize concepts of control system components and mathematical modeling of electrical system, mechanical system, etc. **[K1, K2, K3]**
CO2	Ability of students to identify and implement the concept of time response and frequency response of the system. **[K1, K3]**
CO3	Ability of students to utilize understanding of different plots such as Bode plot, Nyquist plot, Root locus method and Polar plot and implement them for robot applications. **[K2, K3, K4]**
CO4	Ability of students to practically implement knowledge on joint space and task space control scheme in robots. **[K3, K4]**

CO/PO	PO01	PO02	PO03	PO04	PO05	PO06	PO07	PO08	PO09	PO10	PO11	PO12
CO1	3	3	3	3	2	-	-	-	1	1	-	3
CO2	3	3	3	3	2	-	-	-	1	1	-	3
CO3	3	3	3	3	-	-	-	-	1	1	-	3
CO4	3	3	3	3	-	-	-	-	1	1	-	3

Course Content	**No of Lectures**
Unit I **Introduction to Control System:** Elements of control systems, concept of open loop and closed loop systems, Examples and application of open loop and closed loop systems. Concept of feedback and Automatic control, Effects of feedback. Transfer function of electrical, mechanical (translational and rotational) System. Force Voltage and Force Current analogies. Transfer function model of AC & DC servomotor, potentiometer & tacho-generator. Block diagram reduction technique and signal flow graph, Mason's rule, Signal flow graph of electrical network.	[10]

Conversion of BDR to SFG and vice versa.	
Unit II **Time Domain Analysis:** Time domain analysis of a standard second order closed loop system. Concept of un-damped natural frequency, damping, overshoot, rise time and settling time. Dependence of time domain performance parameters on natural frequency and damping ratio. Step and Impulse response of first and second order systems. Effects of Poles and Zeros on transient response. Stability by pole location. Routh-Hurwitz criteria and applications. Error Analysis: Steady state errors in control systems due to step, ramp and parabolic inputs. Concepts of system types and error constants. Root locus Techniques: Definition and properties of root locus, rules for plotting root locus, stability analysis using root locus. **Frequency Domain Analysis:** Polar plots, Bode plot, stability in frequency domain, Nyquist plots, Nyquist stability criterion. Gain margin and phase margin via Nyquist diagram and Bode plots.	[10]
Unit III: **State Variable Analysis**: Introduction to state variable, General state space representation, State space representation of Electrical and Mechanical systems. Conversion between state space and transfer function. Alterative representations in state space: (Phase variable, canonical, parallel & cascade). Similarity transformations, diagonalizing a system matrix. Laplace Transform solution of state equation, stability in state space, pole placement topology, controller design by pole placement topology in phase variable form, controllability, controllability matrix, controllability by inspection. Introduction to Observer/estimator, observability, observability matrix, observability by inspection, observer design by pole placement.	[10]
Unit IV **Introduction to the Compensator:** Basic concept of compensator design, requirement, cascade compensator, feedback compensator, gain compensation, lag, lead, and lag-lead compensator, proportional, derivative, integral Compensation, physical realization of compensator with passive and active components, basic block diagrams of a compensated closed loop control system.	[10]
Textbooks: [T1] Nise N. (2004) *Control system engineering.* 2nd edition [T2] Kuo B. C. (1995) *Digital Control Systems*, Oxford series. 2nd Edition [T3] Wilkie J, Johnson M., Katebi R. (2002) *Control Engineering: An Introductory Course,* Palgrave MacMillan	
Reference Books: [R1] Dorf R.C., (1998) *Modern control Engineering*. SH Bishop, & Wesley edition, Eighth Edition. [R2] J. J. Azzo, Houpis C. H., Sheldon S. N., Dekkar M. (2003). *Linear Control Analysis and design with MaTLAB*, ISBN 0824740386	