University School of Automation and Robotics
GURU GOBIND SINGH INDRAPRASTHA UNIVERSITY
East Delhi Campus, Surajmal Vihar
Delhi - 110092

Paper Code: ARA 208
Subject: Control Theory and Robot Control Systems

L	T/P	Credits
4	-	4

Marking Scheme

1. Teachers Continuous Evaluation: 25 Marks
2. End Term Theory Examination: 75 Marks

INSTRUCTIONS TO PAPER SETTERS: **Maximum Marks : 75**

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

Course Outcomes:

CO1:	Ability of students to utilize concepts of control system components and mathematical modeling of electrical system, mechanical system, etc.
CO2:	Ability of students to identify and implement the concept of time response and frequency response of the system.
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
CO4:	Ability of students to practically implement knowledge on joint space and task space control schemes in robots.

Course Outcomes (CO) to Programme Outcomes (PO) Mapping (Scale 1: Low, 2: Medium, 3: High)

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

Unit I

Introduction to control system: Basic elements of control system, Open and Closed loop control systems, Differential equation representation of physical systems, Transfer function, Mathematical modeling of electrical and mechanical systems (Translational and Rotational), Analogous system, Block diagram reduction techniques, Signal flow graph and Mason's Gain formula **[8]**

Unit II

Time Domain Analysis: Time response analysis-Analysis of transient and steady state behavior of control systems-Standard test signals –Time response of First order system- step, ramp and impulse response analysis-Second order system – step response analysis- steady state error-generalized error co-efficient–Response with P, PI, PD and PID controllers-Analysis using software packages **[10]**

Frequency Domain Analysis: Frequency response-Frequency domain specifications-

Approved by: PoS of USAR: 1/08/22

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Correlation between time domain and frequency domain specifications-Bode plot- Stability analysis using Bode plot- transfer function from Bode plot-Polar plot-Analysis using software packages

Unit III

[10]

Stability & Compensation Techniques: Concepts, absolute, asymptotic, conditional and marginal stability, Routh–Hurwitz and Nyquist stability criterion, Root locus technique and its application. Concepts of compensation, series/parallel/ series-parallel/feedback compensation, Lag/Lead/Lag-Lead networks for compensation, compensation using P, PI, PID controllers
Joint Space and Task Space Control Schemes: Position control, velocity control, trajectory control and force control

Unit IV

[12]

Robot Control and Observer Schemes: Proportional and derivative control with gravity compensation, computed torque control, sliding mode control, adaptive control, observer based control, robust control and optimal control. Design based on acceleration, velocity and position feedback. Numerical simulations using MATLAB

Text Books:

1. B. C. Kuo, (2001) *Automatic control system*, Prentice Hall of India, 7th edition.
2. I.J. Nagrath, M. Gopal, (2011) *Control Systems Engineering*, Fifth Edition, New Age International, New Delhi.
3. Kelly, R., Davila, V. S., & Perez, J. A. L. (2005). *Control of robot manipulators in joint space*. Springer Science & Business Media.
4. Sabanovic, A., & Ohnishi, K. (2011). *Motion control systems*. John Wiley & Sons.
5. Tewari, A. (2002). *Modern control design with MATLAB and SIMULINK* (Vol. 1). Chichester: Wiley.

Reference Books:

1. Nise, N. S. (2011). *Control system engineering*, john wiley & sons. *Inc, New York*.
2. Stefani, R. T., Shahian, B., Savant, C. J., and Hostetter, G. H. (2002). *Design of feedback control systems* (pp. 44-45). Oxford: Oxford University Press.
3. Ogata, K., (2010) *Modern Control Engineering*, Prentice Hall of India Pvt. Ltd., 2010.
4. S. P.Eugene Xavier, (2004) *Principles of control systems*, S. Chand & Company
5. Richard C. Dorf, Robert H. Bishop., (2011). *Modern control systems,* Pearson.

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