IC6501 CONTROL SYSTEMS L T P C 3 1 0 4

OBJECTIVES:

- To understand the use of transfer function models for analysis physical systems and introduce the control system components.
- To provide adequate knowledge in the time response of systems and steady state error analysis.
- To accord basic knowledge in obtaining the open loop and closed–loop frequency responses of systems.
- To introduce stability analysis and design of compensators
- To introduce state variable representation of physical systems and study the effect of state feedback

UNIT I SYSTEMS AND THEIR REPRESENTATION 9

Basic elements in control systems – Open and closed loop systems – Electrical analogy of mechanical and thermal systems – Transfer function – Synchros – AC and DC servomotors – Block diagram reduction techniques – Signal flow graphs.

UNIT II TIME RESPONSE 9

Time response – Time domain specifications – Types of test input – I and II order system response – Error coefficients –Generalized error series – Steady state error – Root locus construction- Effects of P, PI, PID modes of feedback control –Time response analysis.

UNIT III FREQUENCY RESPONSE 9

Frequency response – Bode plot – Polar plot – Determination of closed loop response from open loop response - Correlation between frequency domain and time domain specifications- Effect of Lag, lead and lag-lead compensation on frequency response- Analysis.

UNIT IV STABILITY AND COMPENSATOR DESIGN 9

Characteristics equation – Routh Hurwitz criterion – Nyquist stability criterion- Performance criteria – Lag, lead and lag-lead networks – Lag/Lead compensator design using bode plots.

UNIT V STATE VARIABLE ANALYSIS 9

Concept of state variables – State models for linear and time invariant Systems – Solution of state and output equation in controllable canonical form – Concepts of controllability and observability –Effect of state feedback. TOTAL (L:45+T:15): 60 PERIODS

OUTCOMES: Ability to understand and apply basic science, circuit theory, theory control theory, Signal processing and apply them to electrical engineering problems.

TEXT BOOKS:

1. M. Gopal, Control Systems, Principles and Design‘, 4th Edition, Tata McGraw Hill, New Delhi,2012
2. S.K.Bhattacharya, Control System Engineering, 3rd Edition, Pearson, 2013.
3. Dhanesh. N. Manik, Control System, Cengage Learning, 2012.

REFERENCES:

1. Arthur, G.O.Mutambara, Design and Analysis of Control; Systems, CRC Press, 2009.
2. Richard C. Dorf and Robert H. Bishop, ― Modern Control Systems‖, Pearson Prentice Hall,2012.
3. Benjamin C. Kuo, Automatic Control systems, 7th Edition, PHI, 2010.
4. K. Ogata, Modern Control Engineering‘, 5th edition, PHI, 2012.
5. S.N.Sivanandam, S.N.Deepa, Control System Engineering using Mat Lab, 2nd Edition, Vikas Publishing, 2012.

6. S.Palani, Anoop. K.Jairath, Automatic Control Systems including Mat Lab, Vijay Nicole/ Mcgraw Hill Education, 2013.

S.No	Topics to be Covered	CO Statement	Book No [Page No]	Delivery method	Knowledge Level (Bloom's Taxonomy)	Delivery periods
UNIT I: SYSTEMS AND THEIR REPRESENTATION						
1.	Basic elements in control systems Open and closed loop systems	C3 06.01	R1(1-8)R3(1-25) R2(2-20)	Chalk & board / PPT	U	1
2.	Transfer function	C3 06.01	R1(55-58)R3(46-58)	Chalk & board / PPT	U	1
3.	Electrical analogy of mechanical systems	C3 06.01	R1(85-92) R3(77-86) R2(25-36)	Chalk & board / PPT	U	2
4.	Electrical analogy of thermal systems	C3 06.01	R1(188-191)R2(36-38) R3(100-109)	Chalk & board / PPT	U	2
5.	Block diagram reduction techniques	C3 06.01	R3(151-159) R2(54-62)	Chalk & board / PPT	U	2
6.	Signal flow graphs	C3 06.01	R1(104-111) R3(159-168) R2(62-72)	Chalk & board / PPT	U	2
7.	AC and DC servomotors	C3 06.01	R3(168-205)	Chalk & board / PPT	U	1
8.	Synchros	C3 06.01	R2(82-121)	Chalk & board / PPT	U	1
Assignment 1	**Date of Announcement(DOA) :**		**Date Of Submission(DOS)**			
UNIT II: TIME RESPONSE						
9.	Time response	C3 06.02	R1(219-224) R2(195-199)	Chalk & board / PPT	U	1
10.	Time domain specifications	C3 06.02	R3(361-365)	Chalk & board / PPT	U	2
11.	Types of test input – I and II order system response	C3 06.02	R3(366-376) R1(224-233)	Chalk & board / PPT	U	2
12.	Error coefficients –	C3 06.02	R1(288-293)	Chalk &	U	2

	Generalized error series – Steady state error		R3(390-395) R3(409-417) R2(210-214)	board / PPT		
13.	Effects of P, PI, PID modes of feedback control- Time response analysis	C3 06.02	R1(396-406) R3(409-417)	Chalk & board / PPT	U	2
14.	Root locus construction	C3 06.02	R1(337-416)	Chalk & board / PPT	U	3
	NPTEL Video					
UNIT III: FREQUENCY RESPONSE						
15.	Frequency response	C3 06.03	R3(612-617) R2(346)	Chalk & board / PPT	U	2
16.	Correlation between frequency domain and time domain specifications	C3 06.03	R3(617-622) R2(347-352)	Chalk & board / PPT	U	2
17.	Bode plot	C3 06.03	R1(497-515) R2(371-376) R3(580-585)	Chalk & board / PPT	U	2
18.	Polar plot	C3 06.03	R1(523-539)R3(558-562) R3(597-602)	Chalk & board / PPT	U	2
19.	Determination of closed loop response from open loop response	C3 06.03	R2(367-370)R3(584-588) R1(575-583)R2(409-413)	Chalk & board / PPT	U	2
20.	Effect of Lag, lead and lag-lead compensation on frequency response-Analysis.	C3 06.03	R1(621-629)R3(467-481) R2(435-437)	Chalk & board / PPT	U	2
UNIT IV: STABILITY AND COMPENSATOR DESIGN						
21.	Characteristics equation	C3 06.04	R3(330-338)R2(270-277)	Chalk & board / PPT	U	2
22.	Routh Hurwitz criterion	C3 06.04	R1(275-280) R3(339-356) R2(277-295)	Chalk & board / PPT	U	2

23.	The Nyquist stability criterion	C3 06.04	R3(535-543)R2(381-394)	Chalk & board / PPT	U	3
24.	Performance criteria – Lag, lead and lag-lead networks	C3 06.04	R1(621-629)R3(467-481) R2(435-437)	Chalk & board / PPT	U	2
25.	Lag/Lead compensator design using bode plots.	C3 06.04	R1(621-638)R3(467-489) R2(435-440)	Chalk & board / PPT	U	3
UNIT V: STATE VARIABLE ANALYSIS						
26.	Concept of state variables	C3 06.05	R1(29-32)	Chalk & board / PPT	U	2
27.	State models for linear and time invariant Systems	C3 06.05	R1(32-39) R1(649-655)	Chalk & board / PPT	U	2
28.	Solution of state and output equation in controllable canonical form	C3 06.05	R1(660-668)	Chalk & board / PPT	U	2
29.	Concepts of controllability and observability	C3 06.05	R1(675-687)	Chalk & board / PPT	U	3
30.	Effect of state feedback	C3 06.05	R1(723-728)	Chalk & board / PPT	U	3

CO1	understand the control system components and transfer function models of physical systems.
CO2	Analyze the time response of systems and steady state error.
CO3	Apply the basic knowledge in determination of open loop and closed–loop frequency responses.
CO4	Design of compensators and its stability analysis.
CO5	Describe the state variable representation of physical systems and the effect of state feedback.

COURSE OUTCOME	PROGRAMME OUTCOME											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	-	2	-	-	-	-	-	-	-	1
CO2	3	2	2	2	2	-	-	-	2	-	1	2
CO3	3	2	-	2	2	-	-	-	2	-	1	1
CO4	3	2	2	2	2	-	-	-	2	-	1	2
CO5	3	2	1	2	-	-	-	-	-	-	1	2

COURSE OUTCOME	PROGRAM SPECIFIC OUTCOME		
	PO1	PO2	PO3
CO1	3	-	-
CO2	3	2	1
CO3	3	2	1
CO4	3	-	1
CO5	3	2	-

IC6501 Control Systems
Question Bank

UNIT I

1. What is control system?
A system consists of a number of components connected together to Performa specific function. In a system when the output quantity is controlled by varying the input quantity then the system is called control system.

2. What are the two major types of control system?
The two major types of control system are open loop and closed loop

3. Define open loop control system. (NOV 2011,MAY 2013,NOV 2017)
The control system in which the output quantity has no effect upon the input quantity are called open loop control system. This means that the output is not feedback to the input for correction.

4. Define closed loop control system. (NOV 2011,2017)
The control system in which the output has an effect upon the input quantity so as to maintain the desired output values are called closed loop control system.

5. What are the components of feedback control system?
The components of feedback control system are plant , feedback path elements, error detector and controller.

6. What is the mathematical model of a system? (April 2005)
Mathematical model is the mathematical representation of the physical model of a system through use of appropriate physical laws. For most physical systems they are characterized by differential equations. A mathematical model may either be time variant or time invariant.

7. What is electrical analogous of a gear? (April 2005)
Transformer is electrical analogous of a gear.

8. Explain Mason's gain formula for signal flow graphs. (Nov 2003,April2004,NOV 2008,NOV 2011)) (APR 2010)
According to Mason's Gain formula,

Overall gain, $T = \frac{1}{\Delta} P_K \Delta_K$

Where, T = transfer function of the system,
P_k= forward path gain of kth forward path
Δ = 1 - (sum of individual loop gain) + (sum of gain products of all possible Combinations of two non-touching loops) - (sum of gain products of all possible combination of three non-touching loops)+..................
Δ_K = Δ for the part of the graph which is not touching Kth forward path.

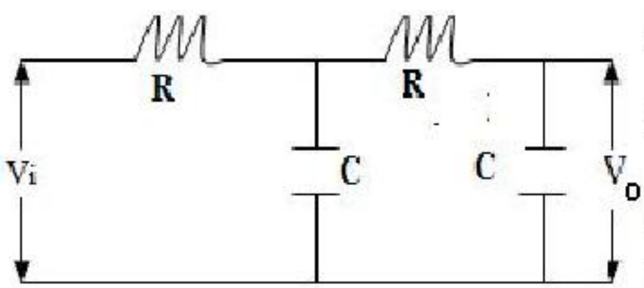
9. What is the force voltage analogy of a mechanical spring? (Nov2004)
The force – voltage analogy of mechanical spring is reciprocal of capacitance (1/C)

10. What are the disadvantages of block diagram representation? (Nov2004)
1. Reduction of block diagram is becoming tedious for complex systems.
2. It is time consuming.
3. Not suitable for MIMO system
4. Not suitable for nonlinear system

11. Mention the equivalent electrical elements for the mass, damper, spring elements in mechanical system. (Nov 2004)

Mech.System Components	Equivalent Electrical Elements	
	Force – Voltage analogous	Force – Current analogous
Mass	Inductance (L)	Capacitance (C)
Damper	Resistance (R)	Reciprocal of resistance (1/R)
Spring	Reciprocal of capacitance (1/C)	Reciprocal of inductance (1/L)

12. Derive the transfer function of the network shown in Fig



$$V_i(s) = \left(R + \frac{1}{Cs}\right) I_1(s) - \frac{1}{Cs} I_2(s) ----------(1)$$

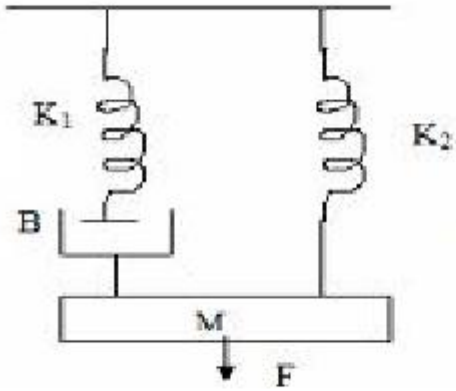
$$0 = \left(R + \frac{2}{Cs}\right) I_2(s) - \frac{1}{Cs} I_1(s) ------------(2)$$

rom(1) & (2)

$$V_i(s) = R^2C^2s^2 + 3R(s+1)/Cs$$

$$\frac{V_0(s)}{V_i(s)} = \frac{1}{R^2C^2s^2 + 3RCs + 1}$$

13. Write the differential equations of the mechanical system shown in Fig



$$B\frac{d}{dt}(x_1 - x_2) + K_1 x_1 = 0$$

$$M\frac{d^2 x_2}{dt^2} + B\frac{d}{dt}(x_2 - x_1) + K_2 x_2 = F(t)$$

14. What do you mean by analogous system?
If the differential equations of systems are identical then the systems are called as analogous systems. E.g. Force Voltage system and Torque – Voltage system are analogous.

15. Mention the basic elements of a closed loop system.(Nov 2014)
Error detector or comparator, controller, actuator or final control element, system to be controlled and sensor or transmitter.

16. State any two advantages of feedback control system.
1. The controlled variable accurately follows the desired value. Feedback in the control loop allows accurate control of the output.
2. It greatly improves the speed of its response.

17. What are the advantages and disadvantages of open loop control systems?(June2014, 2015)
Advantages
1. Open loop control is much simpler and less expensive.
2. No sensors are needed to measure the variable.
Disadvantages
1. Not accurate.
2. There is no compensation for any disturbances entering the system since it has a fixed input.

18. Define the Transfer function of a system. (NOV 2004,MAY 2005,NOV 2008, 2010, 13,14,15)
The transfer function of a system id defined as the ratio between Laplace transform of the output and Laplace transform of the input when initial conditions are zero.

$$\text{Transfer Function} = \left.\frac{\text{Laplace transform of the output}}{\text{Laplace transform of the input}}\right|_{\text{Zero initial conditions}}$$

19. Why closed loop systems have a tendency to oscillate?
In closed loop system, the output is always compared with the input and the controller is going to take corrective action based on the difference between two, it has the tendency to oscillate.

20. State the laws governing mechanical rotational elements.
Newton's law, which states that the applied torque will be equal to the sum of torque produced by all mechanical rotational elements (moment of inertia, viscous friction coefficient, torsional spring stiffness)

21. What is synchros? (APR/MAY2010, MAY 2016)
A synchro is an electromagnetic transducer commonly used to convert an angular position of a shaft into

an electric signal. It is commercially known as a selsyn or an autosyn.

22. Define servo mechanism. (APR/MAY 2010)
The servomechanism is a feedback control system in which the output is mechanical position (or) time derivatives of position (e.g. velocity & acceleration).

23. Explain the use of synchro pair as an error detector.
The synchro error detector is formed by interconnection of synchro transmitter and synchro control transformer. If the rotor of the transmitter rotates through an angle θ from its electrical zero position, the rotor of the control transformer will rotate in the same direction through an angle α from its null position. The net angular separation of the two rotors is equal to $(90 - \theta + \alpha)$. The voltage induced in the control transformer rotor is proportional to the cosine of this angle. If $\phi = \theta - \alpha$, the demodulated errorvoltage= $K_s \phi(t)$.

24. Give the different types of D.C servo motors.
Slotted armature type, Surface wound armature type, Surface wound rotating armature, stationary core type.

25.State the assumptions made while obtaining the transfer function of an armature controlled DC servomotor (April1996)
The armature circuit inductance is negligible.*It is approximated by a linear lumped constant parameter model.

26. What is electrical zero of a synchro?
If the angle between the rotor of synchro transmitter and synchro control transformer is 90 degrees, then the voltage induced in the control transformer rotor is zero.This position is known as the electrical zero position of the control transformer.

27.What are the different types of rotor that are used in AC servo motor?
Squirrel – cage rotor and Drag – cup rotor.

28.What is the advantage of Signal flow graph method?
(i) It follows a generalized procedure (ii)It is easier to simplify even if the system has complex structures (iii)Signal flow graph has a systematic approach, whereas block diagram reduction depends on the complexity of the system.

29.Why negative feedback is preferred in control systems? (NOV 2016,MAY 2017, 2018)
Negative feedback leads to a tight control situation whereby the corrective action taken by the controller forces the controlled variable toward the set point, thus leading the system to oscillate around equilibrium.

30. What is block diagram? (APR 2010,2017)
A block diagram of a system is a pictorial representation of the functions performed by each component of the system and shows the flow of signals. The basic elements of block diagram are blocks, branch point and summing point.

31. What is a signal flow graph? (APR/MAY2010)
A signal flow graph is a diagram that represents a set of simultaneous algebraic equations .By taking L.T the time domain differential equations governing a control system can be transferred to a set of algebraic equations in s-domain.

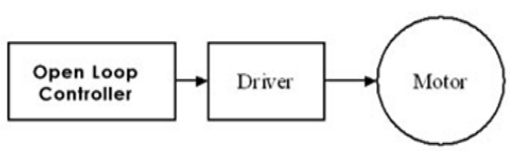
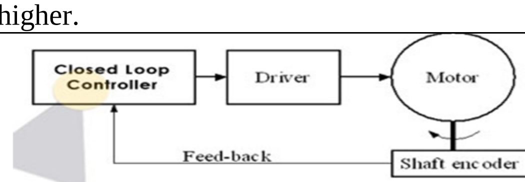
32. What is transmittance?

The transmittance is the gain acquired by the signal when it travels from one node to another node in signal flow graph.

33. Define non touching loop.

The loops are said to be non touching if they do not have common nodes.

34. Distinguish between open loop and closed loop system Open loop Closed loop (APR/MAY 2009)(APR/MAY2010) (Nov 2015)

S.No	OPEN LOOP SYSTEM	CLOSED LOOP SYSTEM
1	An open loop control system acts completely on the basis of input and the output has no effect on the control action.	A closed loop control system considers the current output and alters it to the desired condition. The control action in these systems is based on the output.
2	An open loop control system works on fixed operation conditions and there are no disturbances.	A closed loop control system doesn't encounter and react on external disturbances or internal variations.
3	Open loop control systems are mostly stable.	In closed loop control systems stability is a major issue.
4	There is no effect on gain.	There is no-linear change in system gain.
5	The structure of open loop control system is rather easy to construct. These systems can be easily implemented.	The working principle and structures of closed loop control systems are rather complex and they are often difficult to implement.
6	As an open loop control system is easy to implement, it needs lesser number of components to be constructed. Such systems need good calibration and lesser power rating. The overall cost of these systems is low.	As the principle is complex, a closed loop control system needs larger number of components than an open loop control systems. These systems comparatively need less calibration and higher power rating. The overall cost of these systems is higher.
7		

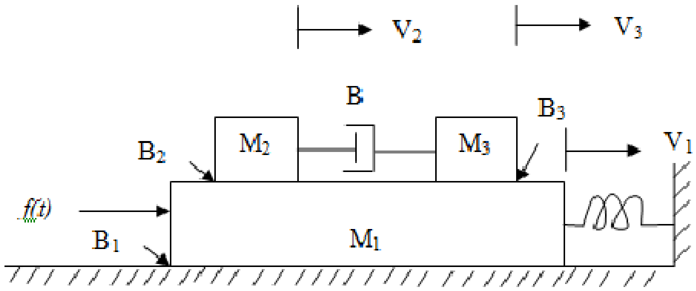
35. What is the differnece between the synchro transmitter and a synchro control transformer? (NOV/DEC 2016)

S.No	synchro transmitter	synchro control transformer
1	The rotor of the synchro transmitter is of dump bell shape	The rotor of the synchro transmitter is of dump cylindrical shape
2	The rotor windings is excited by AC voltage	The induced emf in the rotor is used as an output voltage (error voltage)

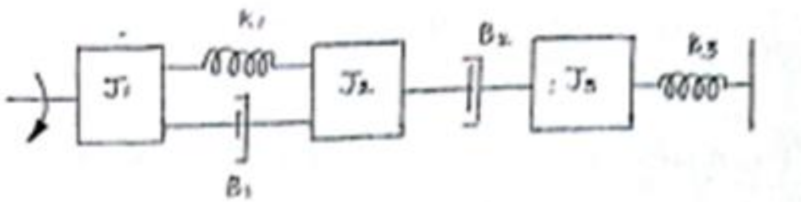
PART-B

1. Derive the transfer function for an armature controlled dc motor. **(April 2008, NOV/DEC 2015) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition page no. 159-163]**

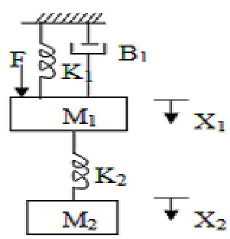
2. Obtain the transfer function of the mechanical systems shown in the following figures. **(NOV/DEC 2016) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 77-86]**



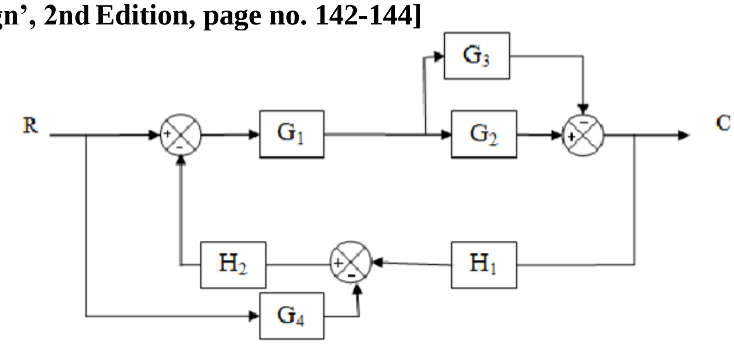
3. Write the differential equations governing the behaviour of the mechanical system shown in figure below. Obtain an analogous electric circuit based on force current analogy. **(MAY/JUNE 2016) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 113-115]**



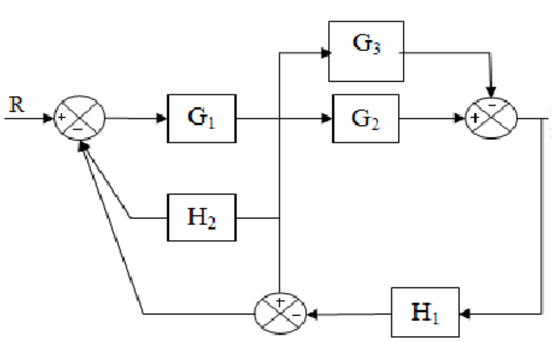
4. Write the differential equations governing the behaviour of the mechanical system shown in figure below. Draw the force voltage and force current electrical analogous circuits and verify by writing mesh and node equations. **(April 2011, NOV 2017) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 113-115]**

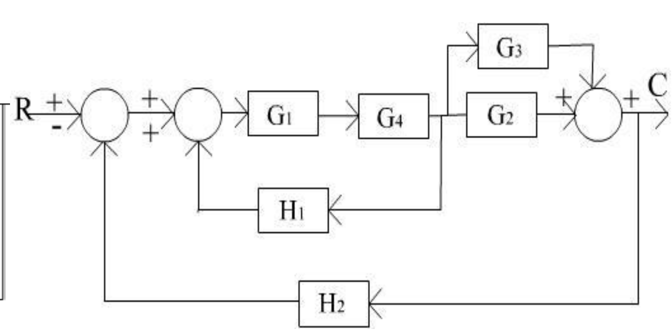


5. Using block diagram reduction techniques, find the closed loop transfer functions of the following system and verify it by using signal flow graph method. **(April 2011) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 142-144]**



6. Draw the signal flow graph and evaluate the closed loop transfer function of a system whose block diagram is given in the following figure. **(APRIL/MAY 2004) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 150-156]**





7.With neat diagram explain the working of AC and DC Servo motor and derive its transfer function.**(Nov 2014) (NOV 2016) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 159-163]**

8. Write the Block diagram reduction rules (alone), to find transfer function of the system. **(Nov 2011) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 142-144]**

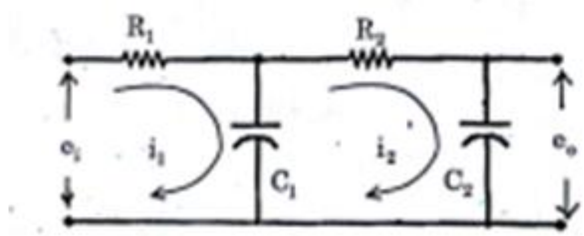
9. Write the working principle of Synchros-Transmitter & Receiver. **[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 159-163]**

10. Derive the transfer function for an armature controlled DC motor (or) DC servomotor. **(April 2008) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 164-174]**

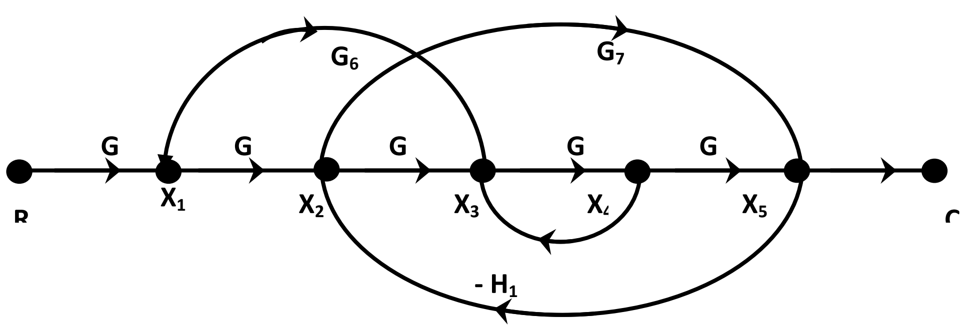
11. Derive the transfer function for a field controlled DC motor (or) DC Servomotor. **(April 2008) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 164-174]**

12. Explain Open loop and Closed loop system with example? **(Nov/Dec 2015) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 13-21]**

13. Construct the block diagram for the simple elctrical network shown in below figure and hence obtain the signal flow graph and transfer function **(NOV/DEC 2016) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 142-144]**

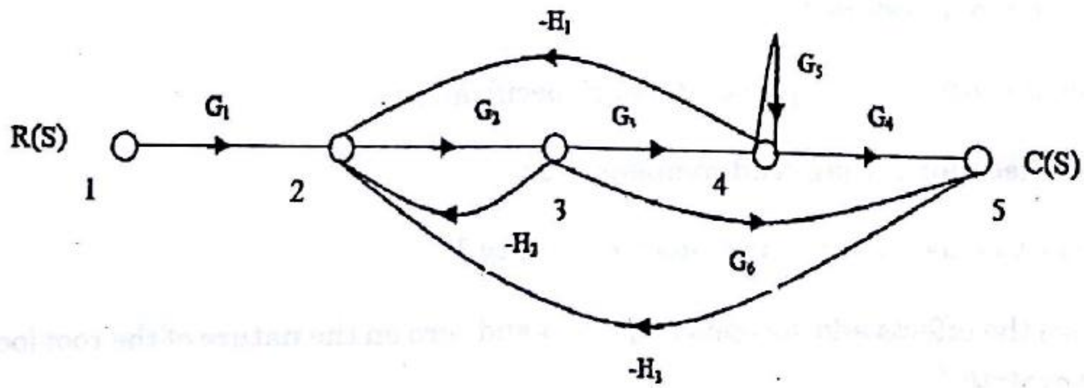


14. Find the transfer of the system whose SFG is drawn in the figure. **(APRIL/MAY03) (MAY/JUN13) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 150-156]**



15. **NOV 2017**

b) Find the overall gain C(S) / R(S) for the signal flow graph shown in Fig. 11 b.



UNIT II

1. What is transient response?

The transient response is the response of the system when the system changes from one state to another.

2. What is an order of a system?

The order of a system is the order of the differential equation governing the system. The order of the system can be obtained from the transfer function of the given system.

3. Define Damping ratio. **(APR/MAY 2009)**

Damping ratio is defined as the ratio of actual damping to critical damping.

4. List the time domain specifications. (NOV/DEC 2008) (APR/MAY2010) (MAY/JUNE 2016)

The time domain specifications are

i. Delay time

ii. Rise time

iii. Peak time

iv. Peak overshoot

5. What are the standard test signals employed for time domain studies?(or)

List the standard test signals used in analysis of control systems?(April 2011)(June2014)

Step input, ramp input, parabolic input and impulse input signals.

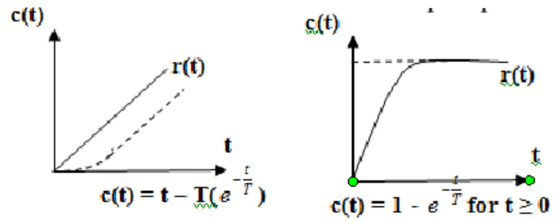
6. What is the initial slope of a step response of a first order system? (April 2004)

$| (dc/dt)t = 0 = (1/T)\ e\text{-}t/T| \ t = 0 = 1 / T$

7. What is steady state error? (April 2011, 2018)

The steady state error is the value of error signal e(t) when t tends to infinity. It is a measure of system accuracy.

8. Plot the time response of the first order system to a unit step and unit ramp input.
Step response for unit step input Step response for unit ramp input



9. Define delay time and peak time.
(a)**Delay time:**It is the time taken for response to reach 50% of the final value, for the very first time.
(b)**Peak time:**It is the time taken for the response to reach the peak value for the very first time.(or) It is the time taken for the response to reach the peak overshoot, Mp.

10. Distinguish between steady state response and transient response.

Steady state response	Transient response
The time response of the system when time tends to infinity	The time response of the system when the input changes from one state to another.

11. Distinguish between generalized error constants over static error constant.

Static error constants	Generalized error constants
1. Do not give the information regarding the variation of error with time.	1. Gives error signal as a function of time.
2. Static error constants can be used only for standard inputs.	2. Using generalized error const. the steady state error can be determined for any type of input.
3. Give the definite values for errors, either 0 or ∞ or a finite value.	3. Give the exact error values.

12. What is ramp signal?
The ramp signal is a signal whose value increases linearly with time from an initial value of zero at t=0.the ramp signal resembles a constant velocity.

13. What is a parabolic signal?
The parabolic signal is a signal whose value varies as a square of time from an initial value of zero at t=0.This parabolic signal represents constant acceleration input to the signal.

14. What are the three constants associated with a steady state error? (APR/MAY 2009)

- Positional error constant (Kp)
- Velocity error constant(Kv)
- Acceleration error constant (Ka)

15. What are the main advantages of generalized error co-efficient? (NOV/DEC 2011)

i) Steady state is function of time.
ii) Steady state can be determined from any type of input

16. What is steady state error?
The steady state error is the value of error signal e(t) when t tends to infinity.

17. What are static error constants?
The Kp, Kv and Ka are called static error constants.

18. Define settling time.
It is the time required for the step response curve of under damped second order system to reach and stay within a specified tolerance band. It is usually expressed as % of final value. The usual tolerable error is 2 % or 5 % of the final value.

19. What is meant by reset time?
In the integral mode of controller, the time during which the error signal is integrated is called the integral or reset time (Ti). In other words in PI control, the time taken by the controller to 'reset' the set point to bring the output to the desired value. U(s) = Kc (1+ (1/TiS)) E(s), where Ti is the integral (or) reset time.

20. Define velocity error constant.
The velocity error constant K_v = Lt s→0 sG(s)H(s). The steady state error in type – 1 system for unit ramp input is given by. $\frac{1}{K_V}$

21. What is the positional error coefficient?
The positional error constant K_p = Lt s→0 G(s)H(s). The steady state error in type – 0 system for unit step input is given by $\frac{1}{1+K_P}$

22. State the rule for finding out the root loci on the real axis. (April2005)
A point on the real axis lies on the locus if the number of open loop poles plus zeros on the real axis to the right of this point is odd.

23. What are the applications of root locus method? (Nov 2003)
Used to study the dynamic response of a system, Visualizes the effects of varying various system parameters on root locations, Provides a measure of sensitivity of roots to the variation in the parameter being considered, It is applicable for single as well as multiple loop systems, Directly we can find the of closed loop response from the given open loop transfer function, We can find the range of open loop gain in which the system is stable in closed loop.

24. State the rule for finding the value of K at any point on the root locus diagram.

$$K = \frac{\text{Product of phasor lenghts from any point So to open loop poles}}{\text{Product of phasor lenghts from any point So to open loop Zeros}}$$

25. State – Angle criterion.
The Angle criterion states that s=sa will be a point on root locus for that value of s, ∟D(s) = ∟G(s) H(s) =odd multiple of 180°system.

26. What is root locus? (May 2012)
It is the locus of the closed loop poles obtained when the system gain ‘K’ is varied from -.∞ to +∞

27. What are asymptotes? How will you find the angle of asymptotes?
Asymptotes are straight lines which are parallel to root locus going to infinity and meet the root locus at infinity. Angles of asymptotes $= \frac{\pm 180^\circ (2q+1)}{n-m}$; $q = 0,1,2,3,....(n-m)$

28. State the rule for obtaining breakaway point in root locus. (May 2011)

To find the break away and break in points, from an equation for K from the characteristics equation, and differentiate the equation of K with respect to s. Then find the roots of equation $\frac{dK}{ds} = 0$ the roots of $\frac{dK}{ds} = 0$ are breakaway or breaking points, provided for this value of root, the gain K should be positive real.

29. What is the advantage of using root locus for design? (Nov 2009)

To find out the potential closed loop pole location. It helps to design good compensator.

30. What is the condition for the system G(S) = K (S + a) / S(S + b) to have a circle in its root locus? (April - 2005)

Two poles should be located adjacently i.e b < a.

31. Explain the function of a PID controller.

It combines all the three continuous controlling modes, gives the output which is proportional to the error signal, proportional to the rate of change of error signal and proportional to the integral of error signal. So it has all the advantages of three individual modes. i.e. less rise time, less oscillations, zero offset and less settling time.ess = 0 can be achieved.

32. What is a derivative controller? What is its effect?

Derivative controller is a device that produces a control signal, which is proportional to the rate of change of input error signal. It is effective only during transient response and does not produce any corrective measures for constant errors u(t) = kde(t)

33. Write the transfer function of the PID controller.(Nov2014)

$$U(S)/E(S) = K_p \left(1 + \frac{1}{T_i s + T_d s} \right)$$

34. What is the effect of PD controller on the system performance?(June2014) (MAY/JUN2013)

The effect of PD controller is to increase the damping ratio of the system and so the peak overshoot is reduced.

35. What is the type and order of the system? (Nov2014, 2017)

Type - no poles of loop transfer function that lies at origin. Order- Maximum power of S in denominator polynomial.

36 What is the significance of integral controller and derivative controller in PID controller?

The proportional controller stabilizes the gain but produces a steady state error. The integral control reduces or eliminates the steady state error.

37. Why derivative controller is not used in control systems? (NOV/DEC 2015)

The derivative controller produces a control action based on the rate of change of error signal and it does not produce corrective measures for any constant error.

38. What is the disadvantage in proportional controller?

The disadvantage in proportional controller is that it produces a constant steady state error.

39. What is the effect of PI controller on system performance? (MAY/JUNE 2016)

The effect of PI controller is to P-I control, steady state error is non-zero and will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future.

40. What are the classification of system based on damping ratio values? (NOV 2015, MAY 2018)

1. undamped system 2. Underdamped system 3. Overdamped system 4. Critical damped system

41. Define Rise time. (APR/MAY2010)

The time taken for response to rise from 0% to 100% for the very first time is rise time.

42. What is the need for a controller? (APR/MAY2010)

The controller is provided to modify the error signal for better control Action

43. What is PI controller? (MAY/JUN2013)

It is device that produces a control signal consisting of two terms –one proportional to error signal and the other proportional to the integral of error signal.

44. What is PD controller? (MAY/JUN2013)

PD controller is a proportional plus derivative controller which produces an output signal consisting of two times -one proportional to error signal and other proportional to the derivative of the signal.

45. What is the effect of PD controller on system performance? (MAY/JUN2013)

The effect of PD controller is to increase the damping ratio of the system and so the peak overshoot is reduced.

46. What is step signal? (NOV/DEC 2008)

The step signal is a signal whose value changes from zero to A at t= 0 and remains constant at A for t>0.

47. What are the main advantages of generalized error co-efficient? (NOV/DEC 2011)

i) Steady state is function of time.
ii) Steady state can be determined from any type of input

48. What are the properties of root locus? (NOV/DEC 2016)

1. Let s1 be the root of characteristic equation 1+K*G1(s)*H1(s) = 0 at s=s1, G1(s)*H1(s) = -1/K hence for s1 to be on RL K should be positive hence the magnitude of G1 (s1)*H1 (s1) should be real and the phase of G1(s)*H1(s) should be odd multiples of 180 Degrees.
2. The K=0 points on the root loci are at the poles of G(s)*H(s). Since at K=0 G1(s)*H1(s) will be infinite, so s must approach the poles of G1(s)*H1(s).
3. Similarly the K=infinite points on the root loci are at the zeros of G(s)*H(s).Since at K=infinite G1(s)*H1(s) will be zero, so s must approach the zeros of G1(s)*H1(s).
4. Each branch in root locus is the locus of one root of characteristic equation as K varies. Hence the number of branches in root locus is equal to the order of characteristic equation, as the number of roots of characteristic equation is equal to the order of the equation. For example a quadratic equation of the form a*s2 + b*s + c = 0 with order 2 will have two roots, a cubic equation a*s3 + b*s2 + c*s + d = 0 of order 3 will have 3 roots.
5. The root locus is symmetrical with respect to the real axis of s-plane. This is due to the fact that the complex roots of an equation always occur in pairs.
6. The root loci are symmetrical with respect to axes of symmetry of pole-zero configuration of G(s)*H(s). The axes of symmetry of pole-zero configuration can be thought as a new complex plane obtained through a linear transformation.

7. When the order of polynomial P(s) n is not equal to the order of polynomial Q(s) m some of the loci will approach infinity in the s-plane. The properties of root loci near infinity in the s-plane are described by asymptotes which are the tangents to the curve at infinity.The number of asymptotes = 2*|n-m|, where n is the number of finite poles and m is the number of finite zeros.
8. The root loci are asymptotic to asymptotes with angles given by θi = (2*i+1)*180/(|n-m|), where n is not equal to m and i = 0,1,2,……,|n-m|-1.
9. The intersect of the 2*|n-m| asymptotes of the root loci lies on the real axis of the s-plane and is given as σ1 = (Σ real parts of poles of G(s)*H(s) – Σ real parts of zeros of G(s)*H(s)) / (n-m)
10. On a given section of real axis, RL are found in the section only if the total number of poles and zeros of G(s)*H(s) to the right of the section is odd.
11. The angle of departure or arrival of a root locus at a pole or zero, respectively, of G(s)*H(s) denotes the angle of the tangent to the locus near the point.
12. The points where the root loci meets the imaginary axis can be found by mans of Routh Hurwitz criteria.
13. Breakaway points on the root loci of an equation correspond to multiple order roots of the equation. The breakaway points must satisfy the equation dG1(s)*H1(s) / ds = 0 in addition to the necessary condition that the breakaway points should lie on root loci
14. n root loci arrive or depart a breakaway pint at 180/n degrees apart.

46. Classify the system based on damping (Nov 2015)

1. under damping ($\xi<1$)
2. critical damping ($\xi=1$)
3. over damping ($\xi>1$)

47. Give the relationship between static and dynamic error coefficients or generalized error coefficients (Nov2015) (NOV/DEC 2016)

$$e_{ss} = \frac{1}{1+k_p} \quad e_{ss} = \frac{1}{k_v} \quad e_{ss} = \frac{1}{k_a}$$

48. What is step signal? (NOV/DEC 2008)

The step signal is a signal whose value changes from zero to A at t= 0 and remains constant at A for t>0.

PART-B

1. Derive the step response of a second order underdamped system **(April 2011) (Nov 2014, 2015, 2017) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 343-352]**

2. The open loop T.F of a servo system with unity feedback system is $G(s) = \frac{10}{s(.1s+1)}$ .Evaluate the static error constants of the system. Obtain the steady state error of the system, when subjected to an input given by the polynomial $r(t) = a_0 + a_1 t + \frac{a_2}{2}t^2$.Also find the generalized error constants and hence e_{ss} . **(April 2014)**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 366-370] NOV 2017

3. A unity feedback control system has an open loop transfer function G(s) $= \frac{5}{s(s+1)}$ Find the rise time, peak overshoot, peak time, settling time, for a step input of 10 units. Also determine the peak overshoot**. (April 2011)**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 343-352]

4. *Sketch the root locus of the* system having $G(s) = \frac{k(s+3)}{s(s+1)(s+2)(s+4)}$ **(May 2013)**

[S.K.Bhattacharya, Control System Engineering, 2nd Edition, page no. 249-251]

5.Sketch the root locus for G(s)H(s) $= \frac{k(s+2)(s+3)}{(s+1)(s-1)}$ **(Nov 2013)**

[S.K.Bhattacharya, Control System Engineering, 2nd Edition, page no. 249-251]

6.Draw the root locus plot for the system whose open loop transfer function $= \frac{k}{(s+2)(s+4)(s^2+6s+25)}$. Find the marginal value of k which causes sustained oscillations and the frequency of these oscillations. (16) **(April 2014)**

[S.K.Bhattacharya, Control System Engineering, 2nd Edition, page no. 249-251]

7. A unity feedback system is characterized by an open loop transfer function G(s) $= \frac{k}{s(s+2)(s+4)}$.

Determine the gain k so that the system will have a damping ratio of 0.5. For this value of k, determine peak overshoot and peak time for a unit step input. (8) **(April 2011) (April 2014)**

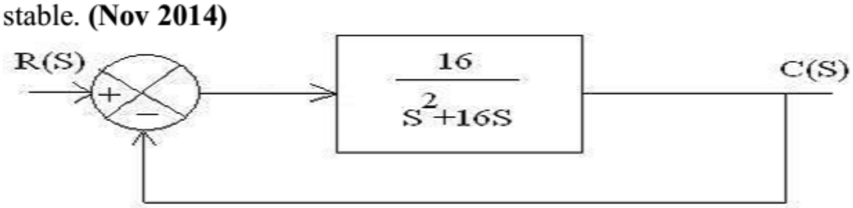
[S.K.Bhattacharya, Control System Engineering, 2nd Edition, page no. 184-193]

8. Obtain the expression for dynamic error co-efficients of the following system is

G(s) $= \frac{10}{s(s+1)}$ **(Nov 2014)**

[S.K.Bhattacharya, Control System Engineering, 2nd Edition, page no. 151-153]

9.Consider the closed loop system shown in Fig 2.Determine the range of k for which the system is stable. **(Nov 2014)**



[S.K.Bhattacharya, Control System Engineering, 2nd Edition, page no. 249-251]

10. Write the Effects of P, PI, PD controller in detail **(MAY/JUNE 2016) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 264-272] (MAY 2018)**

11. Derive the time domain specification of second order system **(MAY/JUNE 2016) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 343-353]**

12. i) Determine the time response of the unity feedback system whose open loop T.F is G(S) =4 / S(S+5) when the input is unit step.

ii) Obtain the time response of first order system when it is subjected to a unit step input **(MAY 2018)**

13. Draw the root locus for the given system $G(S) = K / S(S^2+4S+13)$ **(MAY 2018)**

14. **NOV 2017**

b) Find the static error coefficients for a system whose transfer function is, G (s). H (s) = 10/s (1 + s) (1 + 2s). And also find the steady state error for r (t) = 1 + t + $t_{2/2}$.

UNIT III

1. List any two advantages of frequency response analysis. (April 2005, 2011, 2018)
(a)The absolute and relative stability of the closed loop system can be estimated from the knowledge of the open loop frequency response.(b)The practical testing of system can be easily carried with available sinusoidal signal generators and precise measurement equipments.(c). The transfer function of the complicated functions can be determined experimentally by frequency response tests.(d)The design and parameter adjustments can be carried more easily.(e)The corrective measure for noise disturbance and parameter variation can be easily carried.(f)It can be extended to certain non - linear systems.

2. What is frequency response? (APR 2009, 2017)
A frequency response is the steady state response of a system when the input to the system is a sinusoidal signal.

3.What are the frequency domain specifications? Explain. (APR 2010, NOV 2017)
The frequency domain specifications indicate the performance of the system in frequency domain; they are resonant peak, resonant frequency, Band width, Phase margin,Gain margin

4.Define resonant peak and resonant frequency (June 2014)(Nov 2014)
Resonant peak : The maximum value of the magnitude of closed loop transfer function is called resonant peak. A large resonant peak corresponds to a large overshoot in transient response.
Resonant frequency: The frequency at which the resonant peak occurs is called resonant frequency. This is related to the frequency of oscillation in the step response and thus it is indicative of the speed of transient response.

The resonant frequency, $\omega_r = \omega_n \sqrt{1-2\xi^2}$

5.Distinguish between resonance frequency ωr, and Natural frequency ωn.

Resonance frequency (ω_r)	Natural frequency (ω_n)
The resonant frequency id defined as the frequency at which |G (jω) H (jω)| has a peak value. This is related to the frequency response specification of the control system.	The ωn is called the undamped natural frequency of oscillation and related to the time response specification.

6. What is bandwidth?
The bandwidth is the range of frequencies for which the system gain Is more than 3 dbB. The bandwidth is a measure of the ability of a feedback system to reproduce the input signal, noise rejection characteristics and rise time.

7. Define Cut-off rate?
The slope of the log-magnitude curve near the cut-off is called cut-off rate. The cut-off rate indicates the ability to distinguish the signal from noise.

8. Define the term Gain Margin. (NOV/DEC 2008) (NOV/DEC 2011) (MAY/JUN2013) (Nov2014)

The gain margin is the factor by which the system gain can be increased to drive it to the verge of instability. It may be defined as the reciprocal of the gain at the phase cross over frequency (ωpc). The phase cross over frequency is the frequency at which the phase is 180.°

$$\text{Gain margin } Kg = \frac{1}{|G(j\omega_{pc})|}$$

The gain margin in db can be expressed as

$$Kg\ in\ db = 20\log Kg = 20\log\frac{1}{|G(j\omega_{pc})|}$$

9. Define Phase cross over?

The frequency at which, the phase of open loop transfer functions is called phase cross over frequency w pc.

10. What is phase margin? (NOV/DEC 2008) (NOV/DEC 2011) (MAY/JUN2013)

The phase margin, g is the amount of phase lag at the gain cross over Frequency required to bring system to the verge of instability.

11. Define Gain cross over frequency?

The gains cross over frequency ωgc is the frequency at which the magnitude of the open loop transfer function is unity.

12. What is Bode plot?

The Bode plot is the frequency response plot of the transfer function of a system. A Bode plot consists of two graphs. One is the plot of magnitude of sinusoidal transfer function versus log w. The other is a plot of the phase angle of a sinusoidal function versus log w.

13. What are the main advantages of Bode plot? (APR/MAY2010) (NOV/DEC 2011)

The main advantages are:

i) Multiplication of magnitude can be in to addition.

ii) A simple method for sketching an approximate log curve is available.

iii) It is based on asymptotic approximation. Such approximation is sufficient if rough information on the frequency response characteristic is needed.

iv) The phase angle curves can be easily drawn if a template for the phase angle curve of 1+ jω is available.

14. Define Corner frequency? (APR 2009,2010, 2018)

The frequency at which the two asymptotic meet in a magnitude plot is Called corner frequency.

15. Define phase margin (April 2004)(Nov2014)

The phase margin is defined as the amount of additional phase lag at the gain crossover frequency ω(gc) required to bring the system to the verge of instability.

Phase margin $\gamma = \phi_{gc} + 180°$ Where $\phi_{gc} = \angle G(j\omega) H(j\omega)$ at $\omega = \omega_{gc}$

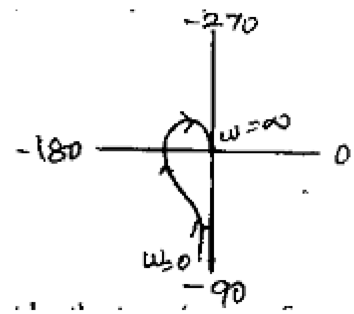
16. Define Gain Crossover Frequency.(April 2011)

The gain crossover frequency is the frequency at which the magnitude of open loop transfer function is unity.

17.**Define phase cross over frequency.**
The phase cross over frequency is the frequency at which the phase of open loop transfer function is 180^{o}.

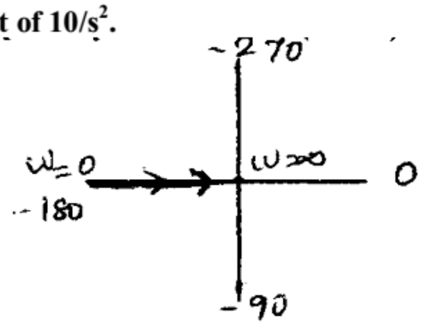
18.Obtain the corner frequencies of the system.G(s)H(s) = (s+0.5)/(s+0.25)(s+4)
Corner frequencies are 0.5, 0.25, and 4.
19.What is meant by the term 'corner frequency'?
Asymptotic straight lines can approximate the magnitude plot. The frequencies corresponding to the meeting point of asymptotes are called corner frequencies. The slope of the magnitude plot changes at every corner frequency.

20. Show the shape of the polar plot for the transfer function K/s (1 +sT1)(1 +sT2) (April-12 NOV/DEC 2015)



21.What is bode plot? State the advantage of Bode plot.
The bode plot is a frequency response plot of the transfer function of a system. It consists of two plots – magnitude plot and phase plot
Magnitude plot: Plot between magnitude in db and log ω for various values of ω
Phase plot: Plot between phase in degrees and log ω for various values of ω. Usually both the plots are plotted on a common X-axis in which the frequencies are expressed in logarithmic scale.
Advantages: (a) The approximate plot can be sketched quickly, (b) The frequency domain specifications can be easily determined,(c) The Bode plot can be used to analyze both open loop and closed loop system.

22. Sketch the polar plot of $10/s^2$.



23.What is a minimum phase transfer function?
A transfer function, which has all poles and zeros in the left half s – plane is known as minimum phase transfer function.

24.What are all pass systems and non-minimum phase transfer function?
All pass systems: The magnitude is unity at all frequencies and the transfer function will have anti symmetric pole zero pattern (i.e. for every pole in the left half of s – plane, there is a zero in the mirror image position with respect to imaginary axis.

Non-minimum phase transfer function: A transfer function, which has one or more zeros in the right half s – plane is known as non-minimum phase transfer function.

25. What are compensators? (Nov2014)
A device inserted into the system for the purpose of satisfying eh specifications is called compensator

26. Why compensation is necessary in feedback control systems?(April 2011)
In feed back control systems compensation is required in the following situations.
1. When the system is absolutely unstable, then compensation is required to stabilize the system and also to meet the desired performance.
2. When the system is stable, then compensation is required to meet the desired performance.

27.What is lag compensator? Give an example? (MAY 2017)
A compensator having the characteristics of a lag network is called lag compensator. If a sinusoidal signal is applied then in steady state output there will be a phase lag with respect to input. E.g. R-C network.

28. What is lead compensator? Give an example?
A compensator having the characteristics of a lead network is called a lead compensator. It gives a phase lead with respect to input if applied with sinusoidal signal. A RC network can realize it.

29. Discuss the effect of adding a pole to the open loop transfer function of the system?
This will reduce the steady -state error and improves steady state performance. Closer the pole towards the origin the lesser will be the steady state error. But addition of pole increases the order of the system, making the system less stable.

30. What is the time domain specifications needed to design a compensator?
Rise time, peak overshoot, settling time, damping ratio, and natural frequency of oscillation.

31. Discuss the effect of adding a zero to the open loop transfer function of the system? (April 2011,2018)
The addition of a zero to open loop transfer function of a system will improve the transient response, reduces the rise time. If the zero is introduced close to origin then the peak overshoot will be larger. If the zero is introduced far away then its effect is negligible.

32. List out the different frequency domain specifications? (APR/MAY 2010)
The frequency domain specifications are i) Resonant peak. ii) Resonant frequency.

33. What are the effects and limitations of phase lag control? (NOV/DEC 2016)
1. For a given forward-path gain K, the magnitude of the forward-path transfer function is attenuated above the gain cross over frequency, thus improving the relative stability of the system.
2. The gain cross over frequency is decreased, and thus the badwidth of the system is reduced
3. The rise time and settling time of the system are usually longer, because the bandwidth is usually decreased
4. The system is more sensitive to parameter variation because the sensitivity function is greater than the bandwidth of the system

34. What does a system with gain margin close to unity or a phase margin close to zero indicate (NOV/DEC 2016)?
A system with gain margin close to unity or a phase margin close to zero indicate that the system is marginally stable.

PART-B

1. Derive the expression for the frequency domain specifications. **(April 2008) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 571-575]**

2. Explain how open loop response can be obtained from closed loop response **(April 2008) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 544-555]**

3. Sketch the polar plot of $G(s) = \dfrac{1}{[s(1+0.5s)(1+0.02s)]}$ **and determine the phase cross over frequency.**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 517-526]

4. Given $G(s) = \dfrac{Ke^{-0.2s}}{[s(s+2)(s+8)]}$**. Find K so that the system is stable with Gain margin equal to 6 db and (b) Phase margin equal to** 45^0 **using bode plots.**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 544-555]

5. Sketch the Bode plot for the following transfer function and obtain gain and phase cross over frequencies. $G(s) = \dfrac{20}{[s(1+0.4s)(0.1s+1)]}$ **(April 2011)**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 544-555]

6. The open loop transfer function of a unity feedback system is given by $G(s) = \dfrac{1}{[s^2(1+s)(1+2s)]}$ **Sketch the polar plot and determine the phase margin and gain margin. (April 2011)**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 517-526]

7. Sketch the Bode plot showing the magnitude in db and phase angle in degrees as a function of log frequencies for the following transfer function $G(s) = \dfrac{75(1+0.2s)}{[s(s^2+16s+100)]}$ **and obtain gain and phase cross over frequencies. (April2014)**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 544-555] (MAY 2018)

8. Discuss the correlation between the time and frequency response of second order system. (April 2014) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 571-575]

9. Using Bode plot of the following system $G(s) = \dfrac{10}{[s(0.1s+1)(0.01s+1)]}$ **and hence obtain the gain cross over frequency. (Nov 2014)**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 544-555] (MAY 2017)

10. Using polar plot determine the gain cross over frequency, phase cross over frequency, gain margin, phase margin feedback system with open loop transfer function $G(s) = \frac{1}{[s\ (1+0.2s)(1+.002s)]}$ **. (Nov 2014)**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 517-526] (MAY 2017

11. Write the Effects of Lag, Lead & Lag-Lead Network [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 264-272]

12. With example write the procedure for bode plot? [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 544-555]

13. **NOV 2017**

Sketch the Bode plot and hence find Gain cross over frequency, Phase cross over Frequency, Gain margin and Phase margin for the function

$$G(s) = \frac{10\,(s+3)}{s\,(s+2)\,(s^2+4s+100)}.$$

14. **NOV 2017**

b) Sketch the polar plot for the following transfer function and find Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin for $G(s) = 400/s\,(s+2)\,(s+10)$.

UNIT IV

1. Define Phase lag and phase lead?

A negative phase angle is called phase lag.
A positive phase angle is called phase lead.

2. What are the two types of compensation?

i. Cascade or series compensation
ii. Feedback compensation or parallel compensation

3. What are the three types of compensators? (MAY/JUN2013)

i. Lag compensator
ii. Lead compensator
iii. Lag-Lead compensator

4. What are the uses of lead compensator?(NOV/DEC 2011)

i. speeds up the transient response
ii. increases the margin of stability of a system
iii. increases the system error constant to a limited extent.

5. What is the use of lag compensator?

Improve the steady state behavior of a system, while nearly preserving its transient response.

6. When is lag lead compensator is required? (APR/MAY2010)(MAY/JUNE 2016)

The lag lead compensator is required when both the transient and steady state response of a system has to be improved

7. What is a compensator? (NOV/DEC 2008) (NOV/DEC 2011) (MAY/JUN2013)
A device inserted into the system for the purpose of satisfying the specifications is called as a compensator.

8. What are the effects of adding a zero to a system? (NOV/DEC 2011)
Adding a zero to a system results in pronounced early peak to system response thereby the peak overshoot increases appreciably.

9. What is a dominant pole? (MAY 2018)
The dominant pole is a pair of complex conjugate pair which decides the transient response of the system.

10. The characteristic equation of a feed back control system is s4 +22 s3 +10s2 + 32 s + K=0. Determine the range of K for which the system is stable. (Nov 2003)

S^4	1	10	K
S^3	22	32	0
S^2	8.545 K 0		
S^1	$\frac{(273.45-22K)}{8.545}$	0	
S^0	K	0	

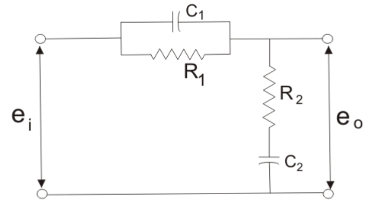
11. What is the condition for the system G(S) = K (S + a) / S(S + b) to have a circle in its root locus? (April 2005)
Two poles should be located adjacently i.e b < a.

12. Define asymptotic stability. (April 2004)
In the absence of the input, the output tends towards zero (the equilibrium state of the system irrespective of initial conditions. This stability concept is known as asymptotic stability.

13. State Hurwitz criterion. (April 2004)
For the stability of the system, it is necessary and sufficient that the n determinants formed from the coefficients a0, a1, a2, a3, an. of the characteristic equation is +ve, where these determinants are taken as the principal minors of the Hurwitz determinant.

a_1	a_0	0	0	0	0
a_3	a_2	a_1	a_0	0	0
.					
.					
a_{2n-1}	a_{2n-1}	0	0	a_{n+1}	a_n

14. Draw the circuit of lag-lead compensator? (Nov 2015)



15. What are the characteristics of an unstable system? (Nov 2004)
The system will give unbounded output for a bounded input, the system has roots with positive real part,the system has repeated roots on jω axis.

16. By Routh–Hurwitz criterion, check the condition for stability of the given system.
$\mathbf{a_0 s^4 + a_1 s^3 + a_2 s^2 + a_3 s + a_4 = 0}$ **(Nov 2004)**

S^4	a_0	a_2	a_4
S^3	a_1	a_3	0
S^2	$b_1 = (a_1 a_2 - a_0 a_3) / a_1 \quad b_2 = a_4$	0	
S^1	$(b_1 a_3 - b_2 a_1)/ b_1$	0	0
S^0	b_2	0	0

$b_2 > 0$; $b_1 a_3 > b_2 a_1$; $a_1 a_2 > a_0 a_3$;

17. Distinguish between relative stability and absolute stability.

Relative stability	Absolute stability
Relative stability is a quantitative measure of how fast the transients die out in the system. It may be measured by relative settling times of each root or pair of roots.	A system is absolutely stable if it is stable for all values of system parameters.
It is defined based on the location of roots with respect to imaginary axis passing through a point other than the origin.	It is defined based on the location of roots with respect to imaginary axis passing through the origin.

18. What is meant by characteristic equation? What is its significance? (MAY/JUNE 2016)
The denominator polynomial of closed loop transfer function equated to zero is the characteristic equation. It tells about the stability of the system.

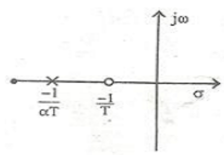
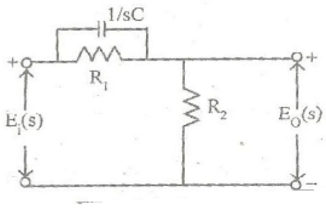
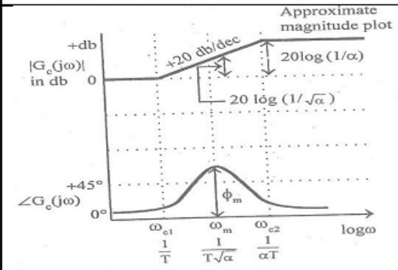
19. State the necessary condition for the Routh's criterion for stability. (NOV/DEC 2015)
A necessary and sufficient condition for stability is that all of the elements in the first column of the Routh array be positive. If this condition is not met, the system is unstable and the number of sign changes in the elements of the first column of the Routh array corresponds to the number of roots of the characteristic equation in the right half of the s – plane.

20. What is dominant pole pair? What is its significance?
The dominant pole is a pair of complex conjugate pole, which decides transient response of the system. In higher order systems the dominant poles are very close to origin and all other poles of the system are widely separated and so they have less effect on transient response of the system.

21.Discuss the effect of adding a pole to the open loop transfer function of the system?(MAY 2018)
This will reduce the steady -state error and improves steady state performance. Closer the pole towards the origin the lesser will be the steady state error. But addition of pole increases the order of the system, making the system less stable.

22. Draw the circuit of lead compensator and draw its pole zero diagram. (May 2011, NOV/DEC 2015)

The lead compensator has a pole at $s = -\frac{1}{\alpha T}$ and a zero at $s = -\frac{1}{T}$.

Pole-zero diagram	Electrical circuit	Bode plot
		

23. State the property of a lead compensator. (Nov 2013)
The lead compensation increases the bandwidth and improves the speed of response. It also reduces the peak overshoot. If the pole introduced by the compensator is not cancelled by a zero in the system, then lead compensation increases the order of the system by one. When the given system is stable/unstable and requires improvement in transient state response then lead compensation is employed.

24. What is lag-lead compensation? (Nov 2009)(May 2016)
A compensator having the characteristics of lag-lead network is called lag-lead compensator. In lag-lead network when sinusoidal signal is applied, both phase lag and phase lead occurs in the output, but in different frequency regions. Phase lag occurs in the low frequency region and phase lead occurs in the high frequency region (i.e) the phase angle varies from lag to lead as the frequency is increased from zero to infinity.

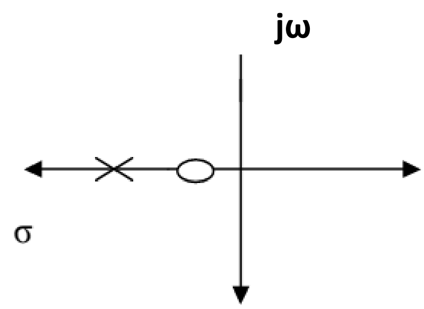
25. Write the transfer function of a typical lag lead compensator. (April 2005)(June 2014)

$$G(s) = \left(\frac{s + \frac{1}{\tau_1}}{s + \frac{1}{\beta\tau_1}}\right)\left(\frac{s + \frac{1}{\tau_2}}{s + \frac{1}{\alpha\tau_2}}\right)$$

26. Write the transfer function of a typical lead compensator and draw its pole-zero plot (April 11)

$$G(s) = \left(\frac{s + \frac{1}{\tau}}{s + \frac{1}{\alpha\tau}}\right)$$

Pole zero plot



27. What is the need for lead and lag compensation? (April 2004)
To improve the system performance lead and lag compensators are needed in control system. Lead compensators are used to improve transient performance. Lag compensators are used to improve the steady state performance.

28. How are the locations of roots of characteristic equation related? (June 2014)
a)If all the roots of the characteristic equations have –ve real parts, the system is bounded Input bounded output stable.
b)If any root of the characteristic equation has a +ve real part the system is unbounded and the impulse response is infinite and the system is unstable.
c)If the characteristic equation has repeated roots on the j axis the system is limitedly stable.
d)If the characteristic equation has non-repeated roots on the j Stable.

29.State Nyquist stability criterion.(May 2010,May 2012, May 2013) (June 2014) (May 2016, 2017)
If G(s)H(s) contour in the G(s)H(s) plane corresponding to Nyquist contour in s-plane encircles the point -1+j0 in the anti clockwise direction as many times as the number of right half of s-plane poles of G(s)H(s). Then the closed loop system is stable.

30. What is the necessity of compensation in feedback control system? (June 2014) (Nov 2015)
To meet the desired specifications, additional devices or components are introduced into system to alter the behaviour.

31. State-Magnitude criterion.   (APR/MAY 2009)
The magnitude criterion states that s=sa will be a point on root locus if for that value of s , | D(s) | = |G(s)H(s) | =1

32. What are the notions for the system stability to be satisfied for a linear time invariant system to be stable? (NOV/DEC 2016)
1. System is excited by bounded input bounded output is also bounded and controllable.
2. In the absence of the input, output must tend to zero irrespective of the initial conditions

33. Why frequency domain compensation is usually carried out using the bode plot? (NOV/DEC 2016)
The bode plots are easy to draw and modify. Further the gain adjustments are conveniently carried out and the error constants are always clearly in evidence.

PART-B

1. Sketch the Nyquist plot for the system whose open loop transfer function. (MAY/JUNE 2016)

$$G(s)\,H(s) = \frac{K(s+2)}{[s(s+3)(s+6)]}$$

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 517-526]

2. Construct the Routh array and determine the stability of the system represented by the characteristic equation $\mathbf{s^5+s^4+4s^3+24s^2+3s+63=0}$. Comment on the location of the roots of characteristic equation **(April 2011) (MAY/JUNE 2016)**
[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 314-325]

3. Explain in detail the design procedure of lag compensator using Bode plot. **(April 2014) (MAY/JUNE 2016) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 629-670]**

4. The open loop transfer function of a unity feedback control system is $G_f(s)=\dfrac{k}{s(s+1)(s+2)}$

Design a suitable lag-lead compensator so as to meet the following specifications: static velocity error constant K_v = 10 sec^{-1}, phase margin = 50° and gain margin ≥ 10db. (May 2011)
[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 629-670] (MAY 2017)

5. Explain in detail the design procedure of lead compensator using Bode plot. **(May 2013) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 629-670]**

6. The open loop transfer function of a unity feedback control system is given by, By applying Routh criterion discuss the stability of the closed system as a function of K. Determine the values of K which will cause sustained oscillations in the closed loop system. What are the corresponding frequencies? **(April 2014)** $\mathbf{G(s)=\dfrac{K}{[(s+2)(s+4)(s^2+6s+25)]}}$ **[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 629-670]**

7. Explain the electric network realization of lead compensator and also its frequency response characteristics. **(April 2014, NOV 2017) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 371-378]**

8. A unity feedback control system has an open loop transfer function $G(s)=\dfrac{5}{[s(s+1)(0.5s+1)]}$ Design a suitable compensator such to maintain Phase margin of atleast 40°. **(Nov 2014)[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 629-670]**

9. State Nyquist stability criterion (8 Mark) **[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 517-520]**

10. Consider the unity feedback whose open loop transfer function is G(S)= $\dfrac{K}{[s(0.1s+1)(0.2s+1)]}$
system to be compensated to meet the following specifications
Static velocity error constant = 30 sec, Phase margin ≥ 50°, Bandwidth w_1=12 rad/ sec. **(Nov 2014)**
[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no. 629-670]

11. Using Routh Hurwitz Stability find the range of K for stability of unity feedback system whose open loop transfer function is G(S) =K / S(S+1)(S+2) **(MAY 2018)**
12. Sketch the Nyquist plot for the system whose open loop transfer function G(S)H(S)=K$(1+S)^2$ / S^3 **(MAY 2018)**
13. **NOV 2017**

a) A unity feedback control system has an open loop transfer function G (s) = K (s + 9) / s (s^2 + 4s+ 11). Sketch the root locus.

(OR)

b) Determine the stability of closed loop system by Nyquist stability criterion, whose open loop transfer function is given by, G (s). H (s) = (s + 2) / (s+ 1) (s – 1).

UNIT V

1. Define state and state variable. (Nov 2012)(May 2013)
State: the state is the condition of a system at any time instant.
State variable: a set of variables which describe the state of the system at any time instant are called state variables.

2. What is state space? (May/June 2016)
The set of all possible values which the state vector X(t) can have at time 't' forms the state space of the system.

3. What is input and output space?
The set of all possible values which the input vector U(t) can have at time 't' forms the state space of the system. The set of all possible values which the output vector Y(t) can have at time 't' forms the state space of the system.

4. What is meant by sampled data control system? (Nov 2012)
When the signal or information at any or some points in a system is in the form of discrete pulses, then the system is called discrete data system or sampled data system.

5. What is meant by quantization? (May 2011)(May 2012)
The process of converting a discrete-time continuous valued signal into a discrete-time discrete valued signal is called quantization. In quantization the value of each signal sample is represented by a value selected from a finite set of possible values called quantization levels.

6. Explain the term sampling and sampler?
Sampling is a process in which the continuous time signal is converted into adiscrete time signal by taking samples of the continuous time signal at discrete time instants. Sampler is a device which performs the process of sampling.

7. State Shanon's sampling theorem.
It states that a band limited continuous time signal with highest frequency fm hertz, can be uniquely recovered from its samples provided that the sampling rate Fs is greater than or equal to 2fm samples per second.

8. Differentiate digital and analog controllers

Analog controller	Digital controller
1. complex	1. simple
2. costlier than digital controller	2. less costlier than analog controller
3. slow acting	3. fast acting
4.non-programmable	4. programmable

9. What are hold circuits?
Hold circuits are devices used to convert discrete time signals to continuous tine signals.

10. What is zero-order hold?
The zero order hold is a hold circuit in which the signal is reconstructed such that the value of reconstructed signal for a sampling period is same as the value of last received sample.

11. What is first-order hold?

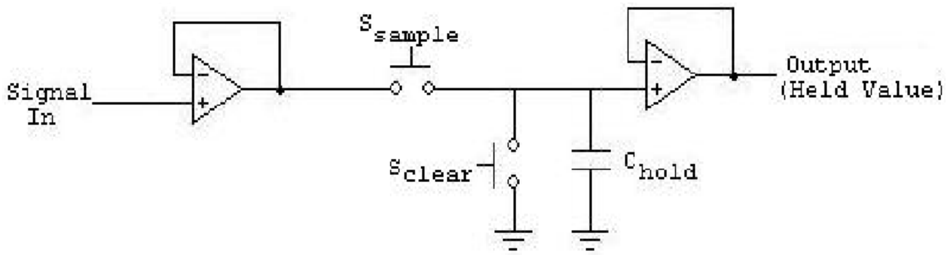
The first order hold is a hold circuit in which the last two signal samples are used to reconstruct the signal for the current sampling period. The reconstructed signal will be a straight line in a sampling period, whose slope is determined by the current sample and previous sample.

12. What are the advantages of state space modelling using physical variables?

a) The state variable can be utilized for the purpose of feedback

b) The implementation of design with state variable feedback becomes straight forward

13. Draw the circuit diagram of sample and hold circuit. (May 2014)



14. When the control system is called sampled data system?

1.When a digital computer or microprocessor or digital device is employed as a part of the control loop.

2.When the control components are used on time sharing basis.

3.When the control signals are transmitted by pulse modulation.

15. What are the properties of state transition matrix? (April/May 2010), (May 2014)

- $\phi(0) = e^{Ax_0} = I \ \ (Identity \ \ Matrix)$
- $\phi^{-1}(t) = \phi(-t)$
- $\phi(t_1 + t_2) = \phi(t_1).\phi(t_2)$
- $[\phi(t)]^n = \phi(nt)$
- $\phi(t_2 - t_1).\phi(t_1 - t_0) = \phi(t_2 - t_0)$

16. Define state equation. (Nov2013)

The state variable model can be represented in the form of n first order differential equations as

$$\frac{dX_1}{dt} = \dot{X}_1(t) = A_{11}X_1(t) + A_{12}X_2(t) +, \ldots\ldots + A_{1n}X_n(t) + B_1u(t)$$

$$\frac{dX_2}{dt} = \dot{X}_2(t) = A_{21}X_1(t) + A_{22}X_2(t) +, \ldots\ldots + A_{2n}X_n(t) + B_2u(t)$$

:

:

$$\frac{dX_n}{dt} = \dot{X}_n(t) = A_{n1}X_1(t) + A_{n2}X_2(t) +, \ldots\ldots + A_{nn}X_n(t) + B_nu(t)$$

17. Write the advantages and disadvantages of sampled data control system?

<u>Advantages:</u>

a) Systems are highly accurate, fast and flexible.

b) Digital transducers used in the system have better resolution

c) The digital components are less affected by noise, non-linearity.

Disadvantages:

a) Conversation of analog signals to discrete time signals and reconstruction introduce noise and errors in the signal.

b) Additional filters have to be introduced in the system if the components of the system do not have adequate filtering characteristics.

18. What are the advantages of state space modelling using physical variables?

a) The state variable can be utilized for the purpose of feedback

b) The implementation of design with state variable feedback becomes straight forward

19. What are the different methods available for computing eAt?

a) Using matrix exponential b) Using Laplacetransforms

c) Using canonical transformation d) Using Cayley-Hamilton theorem

20. What are the advantages of state space approach? (Nov 2011)(May 2013, 2018)

a) The state space analysis is applicable to any type of systems. They can be used for modelling and analysis of linear and nonlinear systems, time variant and time invariant systems and multi input multi output systems.

b) The state space analysis can be performed with initial conditions.

c) The variables used to represent the system can be any variables in the system.

d) Using this analysis the internal states of the system at any time instant can be predicted.

21. When a sampled data control system is stable? Or what are the stability criteria for sampled data control system?

The stability criteria for sampled data control system states that the system is stable if all the poles of the z transfer function of the system lies inside the unit circle in z plane.

22. How the model matrix is determined? (May 2012)

The model matrix M can be formed from eigenvectors. Let m1, m2, m3,....mn be the eigen vectors of a nth order system. Now the modal matrix M is obtained by arranging all the eigen vectors column wise as shown below. Modal matrix = M = [m_1 m_2 m_3 ,.... m_n]

23. Give the concept of controllability. (Nov2013, 2015, MAY 2017, 2018)

A system is said to be completely state controllable if it is possible to transfer the system state from any initial state X(t0) at any other desired state X(t), in specified finite time by a control vector U(t). Controllability test is necessary to find the usefulness of a state variable. If the state variables are controllable then by controlling the state variables the desired outputs of the system are achieved. A general nth order multi-input linear time invariant system $\dot{X} = AX + BU$ is completely controllable if and only if the rank of the composite matrix $Q_C = \left[B : AB : ..... : A^{n-1}B\right]$ is ‘n’

24. Define observability (MAY/JUNE 2016)

A system is said to be completely observable if every state X(t) can be completely identified by measurements of the output Y(t) over a finite time interval. A general nth order multi-input-multi-output time invariant system $\dot{X} = AX + BU$, Y = CX is completely observable if the rank of composite matrix $Q_C = \left[C^T : A^T C^T : ..... : \left(A^T\right)^{n-1} C^T\right]^T$ is ‘n’

25. What is the need for controllability test?

The controllability test is necessary to find the usefulness of a state variable, if the state variables are controllable then by controlling the state variables to the desired output of the systems are achieved.

26. What is the need for observability test?

The observability test is necessary to find weather the state variables are measurable are not. If the state variables are measurable then the state of the system can be determined by practical measurements of the state variables.

27. What are the limitations of state variable feedback? (NOV/DEC 2016)

The limitations of state variable feedback are saturations and nonlinearities

28. What is meant by state of a dynamic system? (NOV/DEC 2015)

The concept of the state of a dynamic system refers to a minimum set of variables, known as state variables that fully describe the system and its response to any given set of inputs

29. List the advantages of Phase variable method

1. Phase variables are simple to realize mathematically
2. Provides a powerful method for state variable information
3. Provides a link between transfer function design approach and time domain approach.

30. List the disadvantages of Phase variable method

1. Phase variables need not always be physical variables of the system. Therefore they may not be directly for measurement and control purposes.
2. When the transfer function is not having zeros, it becomes difficult to realize second or higher derivative outputs.

31. Define State Vector?

State Vector: The 'n' state variables necessary to describe the complete behavior of the system can be considered as 'n' components of a vector X(t) called the state vector at time 't'. The State vector(t) is the vector sum of all the state variables.

32. What are the limitations of conventional time domain and frequency domain analysis over state space approach?

a) Naturally, significant initial conditions in obtaining precise solution of any system, lose their importance in conventional approach.

b) The method is insufficient and troublesome to give complete time domain solution of higher order system.

c) It is not very much convenient for the analysis of Multiple Input Multiple Output System

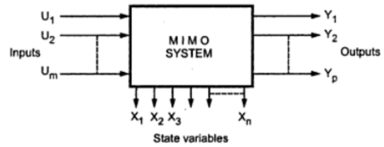
d) It gives analysis of system for some specific types of input like step, ramp etc.

e) It is only applicable to Linear Time Invariant Systems.

f) The classical methods like Root locus, Bode plot etc. are basically trial and error procedures which fail to give the optimal solution required.

33. Define the State model of linear systems?

Consider Multiple Input Multiple Output, nth system as show in figure.



Where,

Number of Inputs = 'm'

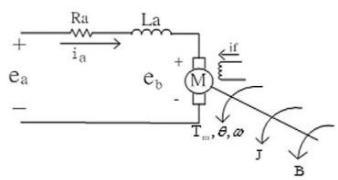
Number of Outputs = ‘p

$$U(t) = \begin{bmatrix} U_1(t) \\ U_2(t) \\ : \\ : \\ U_m(t) \end{bmatrix}, X(t) = \begin{bmatrix} X_1(t) \\ X_2(t) \\ : \\ : \\ X_n(t) \end{bmatrix}, Y(t) = \begin{bmatrix} Y_1(t) \\ Y_2(t) \\ : \\ : \\ Y_p(t) \end{bmatrix}$$

All are column vectors having orders mx1, nx1 and px1 repectively.

$$\begin{aligned} \dot{X}(t) &= A\, x(t) + B\, U(t) \\ Y(t) &= C\, x(t) + d\, U(t) \\ A &= n \times n \text{ matrix, } B = n \times 1 \text{ matrix} \\ C &= 1 \times n \text{ matrix, } d = \text{constant} \\ U(t) &= \text{single scalar input variable} \end{aligned}$$

34. Write the state space equation of armature controller DC motor



The state – eqn. is:

$$\begin{bmatrix} \dot{X}_1 \\ \dot{X}_2 \\ \dot{X}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -\frac{B}{J} & \frac{K_2}{J} \\ 0 & -\frac{K_1}{L} & -\frac{R_a}{L} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \frac{1}{L} \end{bmatrix} e_a(t)$$

35.What is space trajectory. (MAY 2018)

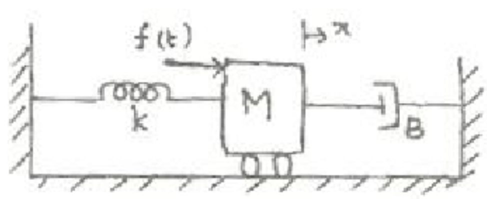
A trajectory or flight path is the path that a moving object follows through space as a function of time. The object might be a projectile or a satellite. For example, it can be anorbit—the path of a planet, an asteroid, or a comet as it travels around a central mass. A trajectory can be described mathematically either by the geometry of the path or as the position of the object over time.

Part B

1. The state space representation of a system is given below. Obtain the transfer function. **(May 2011) [M. Gopal, ‘Control Systems, Principles and Design’, 2nd Edition, page no.782-785]**

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -2 & 1 & 0 \\ 0 & -3 & 1 \\ -3 & -4 & -5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u \quad y = \begin{bmatrix} 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

2. Find the state variable equation for a mechanical system (spring-mass-damper system) shown below. **(Nov 2011) [M. Gopal, ‘Control Systems, Principles and Design’, 2nd Edition, page no.779-780]**



3. Obtain the state space representation of armature controlled D.C. motor with load shown below

4. (i) The state model matrices of a system are given below. Evaluate the observability of the system. **(May 2012) [M. Gopal, ‘Control Systems, Principles and Design’, 2nd Edition, page no.813-819]**

$$A=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & -1\\ 0 & -2 & -3\end{bmatrix}, B=\begin{bmatrix}0\\0\\1\end{bmatrix} \; and \; C=\begin{bmatrix}3 & 4 & 1\end{bmatrix}.$$

5. A system is represented by the state equation X=AX+BU; Y=CX where $A=\begin{bmatrix}0 & 1 & 0\\ 0 & -1 & 1\\ 0 & -1 & -10\end{bmatrix}, B=\begin{bmatrix}0\\0\\10\end{bmatrix} \; and \; C=[100].$ Determine the transfer function of the system. **(May 2013)**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no.782-785]

6. A system is characterized by the transfer function $\frac{Y(s)}{U(s)}=\frac{3}{s^3+5s^2+11s+6}$. Identify the first state as the output. Determine whether or not the system is completely controllable and observable. **(May 2013)**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no.813-819]

7. For the given state variable representation of a second order system given below find the state response for a unit step input and by using the discrete time approximation.

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix}=\begin{bmatrix}0 & 1\\ -2 & -3\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}0\\2\end{bmatrix}[u] \quad \begin{bmatrix}x_1 & 0\\ x_2 & 0\end{bmatrix}=\begin{bmatrix}0\\1\end{bmatrix}$$ **(Nov 2013) (Nov/Dec 2016)**

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no.804-810]

8. Consider the system with the state equation. Check the controllability and observability of the system. (Nov 2013) (MAY/JUNE 2016) (NOV/DEV 2016)

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix}=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ -6 & -11 & -6\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}+\begin{bmatrix}0\\0\\1\end{bmatrix}u$$

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no.813-819]

(i) Obtain the state model of the system described by the following transfer function. $\frac{y(s)}{u(s)}=\frac{5}{s^2+6s+7}$. (8)

[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no.790-801]

9. Derive the expression for linear time-invariant system state and output equation. **(MAY 2016)**
[M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no.779-782]

10. Derive the state feedback effect? **(MAY 2016) [M. Gopal, 'Control Systems, Principles and Design', 2nd Edition, page no.823-830]**

11. Obtain the canonical state model of the following transfer function **G(S)=2(S+5) /(S+2) (S+4) (S+3) (MAY 2018)**

12. Consider the linear system described by the transfer function G(S)=10 /S(S+1) (S+2). Design the feedback controller with the state feedback so that the closed loop poles are located at -2 , -1+j1, -1-j1. (MAY 2018)

13. **NOV 2017**

a) Explain the concepts of controllability and observability.

(OR)

b) Obtain the complete solution of nonhomogeneous state equation using time domain method.

Question Paper Code : 51437

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2014.

Fourth Semester

Electrical and Electronics Engineering

EE 2253/EE 44/EE 1253 A/080280033/10133 IC 401 — CONTROL SYSTEMS

(Common to Instrumentation and Control Engineering and Electronics and Instrumentation Engineering)

(Regulation 2008/2010)

(Common to PTEE 2253 – Control Systems for B.E. (Part-Time) Third Semester – Electronics and Instrumentation Engineering Regulation 2009)

Time : Three hours   Maximum : 100 marks

Note : Polar plot to be issued.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. List the major advantages and disadvantages of open-loop control systems.

2. What are the applications of synchros?

3. What are the standard test signals used in control systems?

4. What is the effect of PD controller on the performance of a system?

5. Define the terms: ' resonant peak', and 'resonant frequency'.

6. What is a constant M circle?

7. How are the locations of roots of characteristic equation related to stability?

8. State the Nyquist stability criterion.

9. What is the necessity of compensation in feedback control system?

10. Write the transfer function of lag-lead compensator.

PART B — (5 × 16 = 80 marks)

11. (a) Write the differential equations for the mechanical system shown in Fig. 1. Obtain an analogous electric circuit based on force-current analogy.

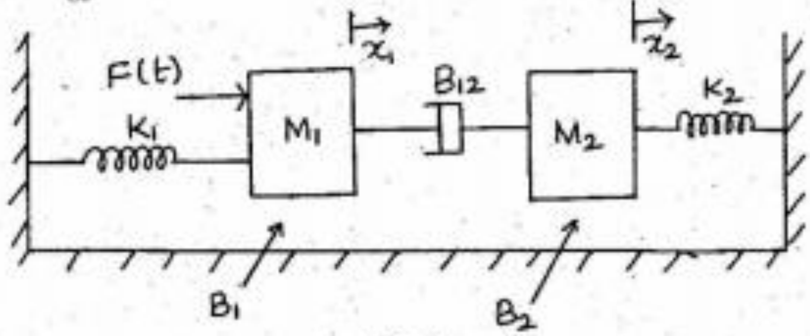


Fig. 1

Or

(b) Consider the signal flow graph shown in Fig. 2. Obtain the closed loop transfer function $\frac{C(s)}{R(s)}$ by the use of Mason's gain formula.

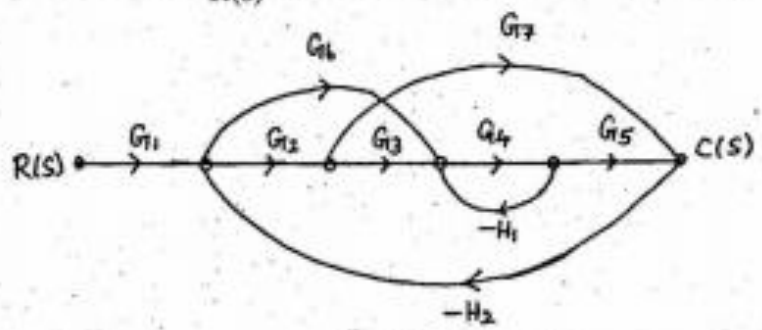


Fig. 2

12. (a) A unity feedback system is characterized by an open loop transfer function $G(s) = \frac{K}{s(s+10)}$.

Determine the gain K so that the system will have a damping ratio of 0.5. For this value of K, determine settling time, peak overshoot and time to peak overshoot for a unit step input.

Or

(b) The open loop transfer function of a servo system with unity feedback is

$$G(s) = \frac{10}{s(0.1s+1)}.$$

Evaluate the static error constants (K_p, K_v, K_a) for the system. Obtain the steady state error of the system when subjected to an input given by the polynomial $r(t) = a_0 + a_1 t + \frac{a_2}{2} t^2$.

13. (a) Sketch the Bode plot showing the magnitude in decibels and phase angle in degrees as a function of log frequency for the transfer function

$$G(s) = \frac{75(1 + 0.2s)}{s(s^2 + 16s + 100)}.$$

From the Bode plot, determine the gain cross-over frequency.

Or

(b) (i) Discuss the correlation between time and frequency response of second order system. (8)

(ii) How the closed loop frequency response is determined from the open loop frequency response using Nichols chart? Explain how the gain adjustment is carried out on the Nichols chart. (8)

14. (a) The open loop transfer function of a unity feedback control system is given by $G(s) = \frac{K}{(s+2)(s+4)(s^2+6s+25)}$.

By applying Routh criterion, discuss the stability of the closed loop system as a function of K. Determine the values of K which will cause sustained oscillations in the closed loop system. What are the corresponding oscillation frequencies?

Or

(b) Sketch the root locus plot of a unity feedback system with an open loop transfer function $G(s) = \frac{K}{s(s+2)(s+4)}$. Find the value of K so that the damping ratio of the closed loop system is 0.5.

15. (a) Explain the electric network realization of a lead compensator and also its frequency response characteristics.

Or

(b) Describe the procedure for the design of lag compensator using Bode plot.

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Reg. No. :

Question Paper Code : 91440

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2014.

Fourth Semester

Electrical and Electronics Engineering

EE 2253/EE 44/EE 1253 A/080280033/10133 IC 401 — CONTROL SYSTEMS

(Common to Instrumentation and Control Engineering and Electronics and Instrumentation Engineering)

(Regulation 2008/2010)

(Also common to PTEE 2253 – Control Systems for B.E. (Part-Time) Third Semester – Electronics and Instrumentation Engineering – Regulation 2009 and 10133 IC 401 – Control System for B.E. (Part-Time) Third Semester – EEE – Regulation 2010)

Time : Three hours

Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What are the basic elements in control systems?

2. Define: transfer function.

3. What is the type and order of the system?

$$G(S) = \frac{K}{S(TS+1)}$$

4. Write the PID controller equation.

5. Write the expression for resonance frequency and peak in terms of time response specifications.

6. Define: Gain margin.

7. What are the location of roots in S – plane for stability?

8. What is meant by $+20db/dec$ slope change?

9. What is the need for compensators?

10. What are the desired performance criteria specified in compensator design?

PART B — (5 × 16 = 80 marks)

11. (a) With neat diagrams, explain the working of AC and DC servo motors. (16)

Or

(b) Using block diagram reduction rules, convert the block diagram of Fig. 1 to a simple loop.

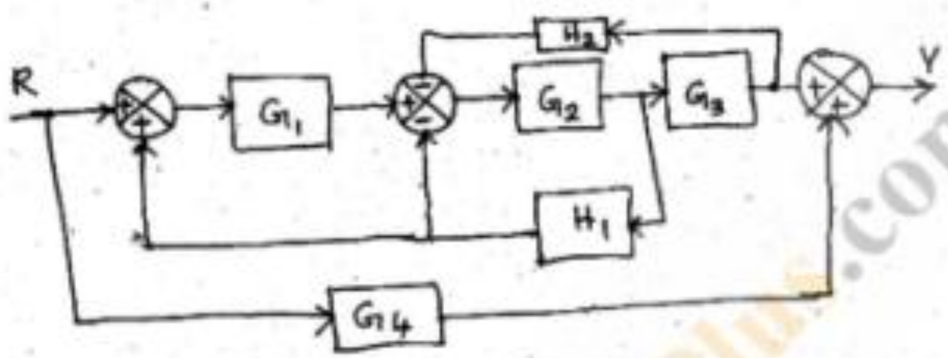


Fig. 1

12. (a) Derive the expression for unit step response of under damped second order system. (16)

Or

(b) Obtain the expression for dynamic error coefficients of the following system $G(S) = \frac{10}{S(1+S)}$ (16)

13. (a) Draw the Bode plot of the following system $GH(S) = \frac{10}{S(0.1\,S+1)(0.01S+1)}$ and hence obtain gain crossover frequency. (16)

Or

(b) Using polar plot, determine gain crossover frequency, phase crossover frequency, gain margin and phase margin of feedback system with open – loop transfer function (16)

$$G(S)H(S) = \frac{10}{S\,(1+0.2S)(1+0.002\,S)}$$

14. (a) Consider the closed – loop system shown in Fig. 2, determine the range of K for which the system is stable. (16)

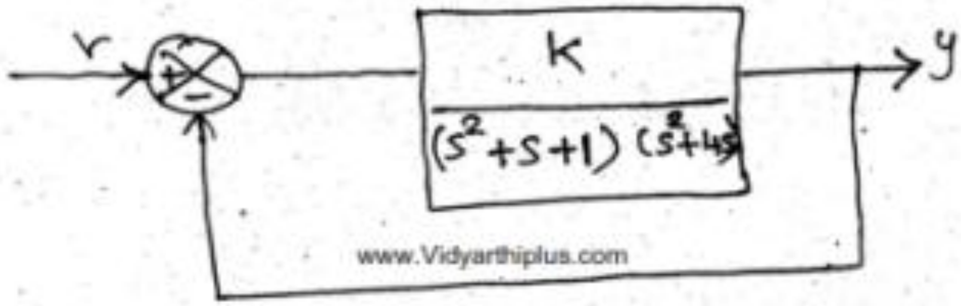


Fig. 2

Or

(b) Draw the root locus of the following system (16)

$$G(S).H(S) = \frac{K}{S(S+1)(S+2)}$$

15. (a) A unity feedback system has an open loop transfer function

$$G(S) = \frac{5}{S(S+1)(0.5S+1)}$$

Design a suitable compensator to maintain phase margin of at least 40°.

Or

(b) Consider the unity feedback system whose open – loop transfer function is $G(S) = \frac{k}{S\,(0.1S+1)(0.2\,S+1)}$

The system is to be compensated to meet the following specifications:

(i) Velocity error constant $k_v = 30$

(ii) Phase margin $\phi m \geq 50°$

(iii) Bandwidth $\omega_1 = 12\ rad/sec$.

Question Paper Code : 71503

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2015.

Fourth Semester

Electrical and Electronics Engineering

EE 2253/EE 44/EE 1253 A/080280033/10133 IC 401 — CONTROL SYSTEMS

(Common to Instrumentation and Control Engineering and Electronics and Instrumentation Engineering)

(Regulation 2008/2010)

(Also common to PTEE 2253 – Control Systems for B.E. (Part-Time) Third Semester – Electronics and Instrumentation Engineering – Regulation 2009 and 10133 IC 401 – Control System for B.E. (Part-Time) Third Semester – EEE – Regulation 2010)

Time : Three hours

Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. State the advantages of closed loop system over the open loop system.

2. Write the force balance equation of ideal dashpot and ideal spring.

3. What is the effect on system performance when a proportional controller is introduced in a system?

4. Distinguish between type and order of the system.

5. Draw the polar plot of $G(s) = 1/(1+sT)$.

6. Define phase and gain margin.

7. What is dominant pole?

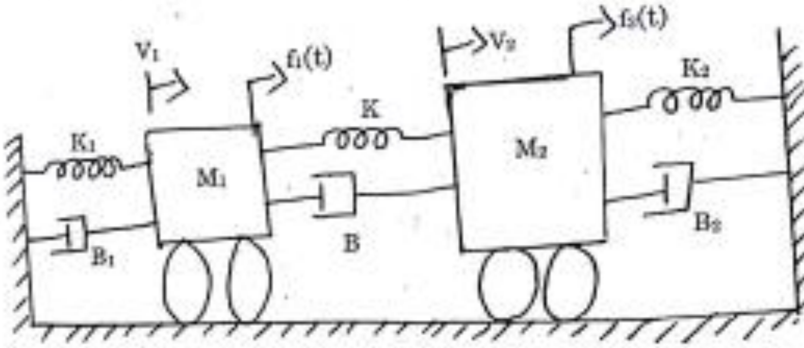
8. State the necessary and sufficient condition for stability.

9. Why compensation is needed in feedback control system?

10. Write the transfer function of lag compensator and draw its pole-zero plot.

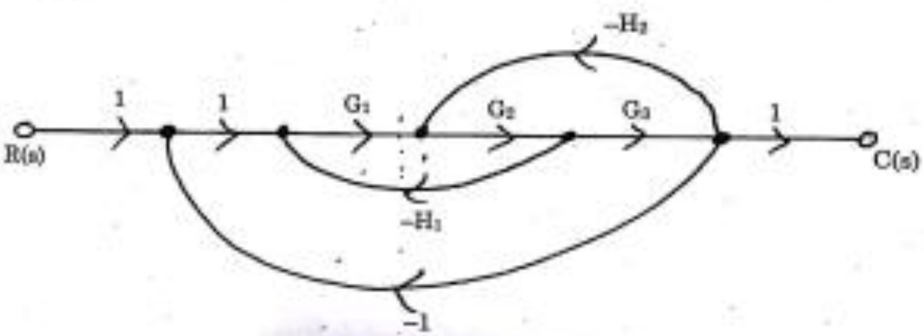
PART B — (5 × 16 = 80 marks)

11. (a) Write the differential equations governing the system and draw the force current and force voltage analogous circuit.



Or

(b) Obtain the transfer function using Mason's Gain formula for the system given.



12. (a) The unity feedback system characterized by open loop transfer function $G(s) = K/[s(s+10)]$. Determine the gain K such that the damping ratio will be 0.5 and find the time domain specifications for a unit step input.

Or

(b) The open loop transfer function of a servo system with unity feedback is $G(s) = 10/[s\ (0.1\ s + 1)]$. Evaluate the static error constants and steady state error of the system when subjected to an input of $r(t) = a_0 + a_1 t + a_2 / 2t^2$.

13. (a) Plot the bode diagram for the given transfer function and determine the gain and phase cross over frequencies of $G(s) = 10/[s(1+0.4s)\ (1+0.1s)]$.

Or

(b) Draw the polar plot for the open loop transfer function with unity feedback system Given by $G(s) = 1/[s^2(1+s)(1+2s)]$. Determine the phase and gain margin.

14. (a) Determine the stability of the given characteristic equation using Routh–Hurwitz Criterion

(i) $S^5 + 4S^4 + 8S^3 + 8S^2 + 7S + 4 = 0$

(ii) $S^6 + S^5 + 3s^4 + 3s^3 + 3S^2 + 2S + 1 = 0.$

Or

(b) Sketch the root locus of the system $G(s) = K/[s(s+2)(s+4)]$ and determine the value of K Such that the damping ratio of the closed loop system is 0.5.

15. (a) Explain the procedure for lag lead compensator using bode plot.

Or

(b) Explain the procedure of lag compensator using bode plot with an example.

Question Paper Code : 27300

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Fifth Semester

Electrical and Electronics Engineering

IC 6501 – CONTROL SYSTEMS

(Common to Instrumentation and Control Engineering and Electronics and Instrumentation Engineering)

(Regulations 2013)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Draw the electrical analog of a thermometer.

2. What is electrical zero position of a synchro transmitter?

3. For the system described by $\frac{C(s)}{R(s)} = \frac{16}{s^2 + 8s + 16}$; find the nature of the time response.

4. Why is the derivative control not used in control systems?

5. Draw the approximate polar plot for a Type 0 second order system.

6. What is the basis for the selection of a particular compensator for a system?

7. How are the roots of the characteristic equation of a system related to stability?

8. Draw the electric lag network and its pole-zero plot.

9. What is meant by 'State' of a dynamic system?

10. When do you say that a system is completely state controllable?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Explain open loop and closed loop control systems with examples. (8)

(ii) Derive the transfer function of an armature controlled DC servomotor. (8)

Or

(b) (i) For the mechanical system shown in Fig. Q 11(b)(i).

(1) Draw the mechanical network diagram and hence write the differential equations describing the behaviour of the system.

(2) Draw the force-voltage and force-current analogous electrical circuits. (6+4)

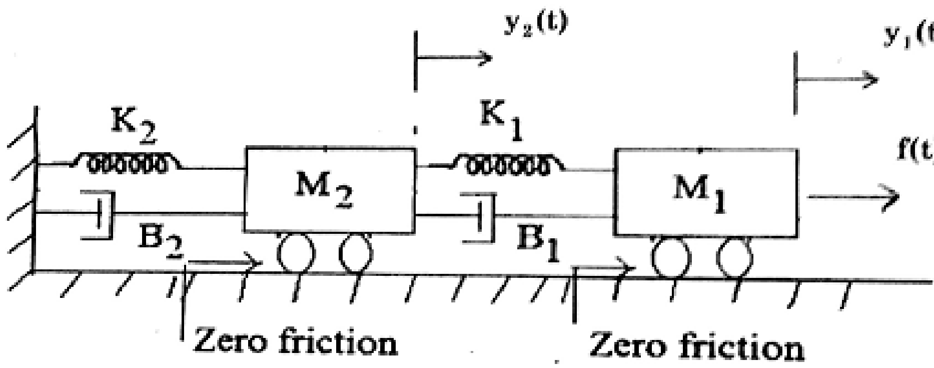


Fig. Q 11(b)(i)

(ii) For a nonunity negative feedback control system whose open loop transfer function is $G(s)$ and feedback path transfer function is $H(s)$, obtain the control ratio using Mason's gain formula. (6)

12. (a) (i) Derive the expressions for the unit step response of a second order

(1) underdamped, and

(2) undamped systems

(8+4)

(ii) Explain briefly the PID controller action with block diagram and obtain its transfer function model. (4)

Or

(b) (i) The open loop transfer function of a unity feedback system is given by $G(s) = \frac{1}{s(1+s)}$. The input to the system is described by $r(t) = 4 + 6t$. Find the generalized error coefficients and steady state error. (6)

(ii) Explain the rules to construct root locus of a system. (10)

13. (a) Construct Bode plot for the system whose open loop transfer function is given below and determine (i) the gain margin, (ii) the phase margin, and (iii) closed-loop system stability.

$$G(s) = \frac{4}{s(1+0.5s)(1+0.08s)}$$ (16)

Or

(b) (i) Explain the use of Nichol's chart to obtain closed loop frequency response from open loop frequency response of a unity feedback system. (8)

(ii) Describe the correlation between time and frequency domain specifications. (8)

14. (a) (i) By use of the Nyquist stability criterion, determine whether the closed-loop system having the following open-loop transfer function is stable or not. If not, how many closed- loop poles lie in the right-half s-plane.

$$G(s)H(s) = \frac{s+2}{(s+1)(s-1)}$$ (6)

(ii) Explain the procedure for the design of a lead compensator using Bode plot. (10)

Or

(b) (i) The open loop transfer function of a unity feedback system is given by $G(s)H(s) = \frac{K}{(s+2)(s+4)(s^2+6s+25)}$. By applying the Routh criterion, find the range of values of K for which the closed loop system is stable. Determine the values of K which will cause sustained oscillations in the closed loop system. What are the corresponding oscillation frequencies? (10)

(ii) Derive the transfer function of the lag-lead compensator. (6)

15. (a) (i) Obtain the state model of the mechanical system shown in Fig.Q11(b)(i) in which $f(t)$ is the input and $y_2(t)$ is the output. (10)

(ii) State and prove the properties of State Transition Matrix. (6)

Or

(b) Check for controllability and observability of a system having following coefficient matrices. (8+8)

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}; \; B = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}; \; C^T = \begin{bmatrix} 10 \\ 5 \\ 1 \end{bmatrix};$$

Reg. No. | | | | | | | | | | | |

Question Paper Code : 57450

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2016

Fifth Semester

Electrical and Electronics Engineering

IC 6501 – CONTROL SYSTEMS

(Common to Electronic and Instrumentation Engineering & Instrumentation and Control Engineering)

(Regulations 2013)

Time : Three Hours **Maximum : 100 Marks**

(Use to Graph Sheet, Semi log sheet Polar sheet is Permissible)
Answer ALL questions.

PART – A (10 × 2 = 20 Marks)

1. What are the basic elements in control systems ?
2. Define Synchros.
3. List the time domain specifications.
4. State the effect of PI-controller on the system performance.
5. Define phase and gain cross over frequencies.
6. What is Lag-Lead compensation ?
7. What is a characteristic equation ?
8. Define Nyquist stability criterion.
9. What is meant by state space ?
10. When a system is said to be completely observable ?

PART – B (5 × 16 = 80 Marks)

11. (a) (i) Compare open and closed loop control systems. **(4)**

(ii) Write the differential equations governing the mechanical rotational system as shown in Fig. 11(a). Draw the both electrical analogous circuits. **(12)**

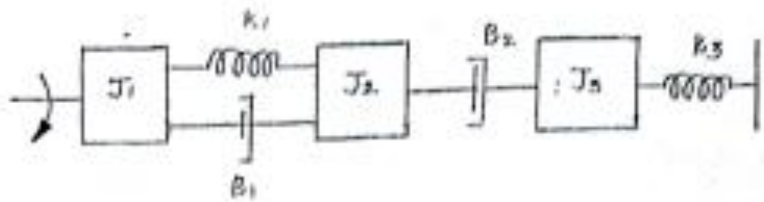


Fig. 11(a)

OR

(b) (i) Convert the given block diagram shown in Fig. 11(b) (i) to signal flow graph for and determine the closed loop transfer function C(s)/R(s). **(12)**

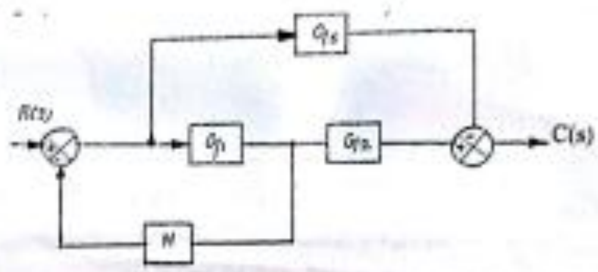


Fig. 11(b) (i)

(ii) Differentiate DC and AC servo motor. **(4)**

12. (a) Derive the time domain specifications of a second order system. **(16)**

OR

(b) (i) For a Unity feedback control system, the open loop transfer function is given by

$$G(S) = \frac{10\,(S + 2)}{S^2\,(S + 1)}$$

(1) Find the position, velocity and acceleration error co-efficients.

(2) Also find the steady state error when the input is

$$R(S) = \frac{3}{S} - \frac{2}{s^2} + \frac{1}{3\,s^3}$$

(12)

(ii) With a neat diagram explain the efect of PD controller in detail. **(4)**

13. (a) Plot the Bode diagram for the following transfer function and determine the Phase and gain cross over frequencies.

$$G(S) = \frac{10}{S\,(1 + 0.4\,S)\,(1 + 0.1S)}$$ **(16)**

OR

(b) The open loop transfer function of a unity feedback system is given by

$$G(S) = \frac{1}{S(1 + S)^2}$$

Sketch the polar plot and determine the gain and phase margin. **(16)**

14. (a) (i) Use R- H criterion to determine the location of the roots and stability for the system represented by Characteristic Equation

$$s^5 + 4s^4 + 8s^3 + 8s^2 + 7s + 4 = 0$$ **(8)**

(ii) Write the procedure for the design of Lag compensator using Bode plot. **(8)**

OR

(b) Draw the Nyquist plot for the system whose open loop transfer function

$$G(S)\,H(S) = \frac{K}{S(S + 2)\,(S + 10)}$$

Determine the range of K for which closed loop system is stable. **(16)**

15. (a) (i) With a neat block diagram, derive the state model and its equations of a Linear multi-input-multi-output system. **(10)**

(ii) Consider the system defined by **(6)**

$$X = Ax + BU$$

$$Y = Cx$$

Where

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}; B = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}; C = [10 \ \ 5 \ \ 1]$$

Check the complete Controllability of the system.

OR

(b) (i) The state model of a system defined by

$$x = Ax + Bu$$

$$y = Cx$$

$$\text{Where } A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}; B = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}; C = [1 \ \ 0 \ \ 0]$$ **(12)**

Obtain the diagonal canonical form of the state model by a suitable transformation matrix.

(ii) Explain about the effect of state feedback. **(4)**

Question Paper Code : 80554

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2016.

Fifth Semester

Electrical and Electronics Engineering

IC 6501 — CONTROL SYSTEMS

(Common to Electronics and Instrumentation Engineering/Instrumentation and Control Engineering)

(Regulations 2013)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Why negative feedback is preferred in control systems?

2. What are the differences between a Synchro transmitter and a Synchro control transformer?

3. Give the relation between static and dynamic error coefficients.

4. State the basic properties of root locus.

5. What does a gain margin close to unity or phase margin close to zero indicate?

6. What are the effects and limitations of phase-lag control?

7. What are two notions of system stability to be satisfied for a linear time-invariant system to be stable?

8. Why frequency domain compensation is normally carried out using the Bode plots?

9. For a first order differential equation described by $\dot{x}(t) = a\,x(t) + b\,u(t)$, draw the block diagram form of state diagram.

10. State the limitations of state variable feedback.

PART B — (5 × 16 = 80 marks)

11. (a) Write the differential equations governing the mechanical system shown in Fig. Q 11(a). Draw the force-voltage and force-current electrical analogous circuits. (16)

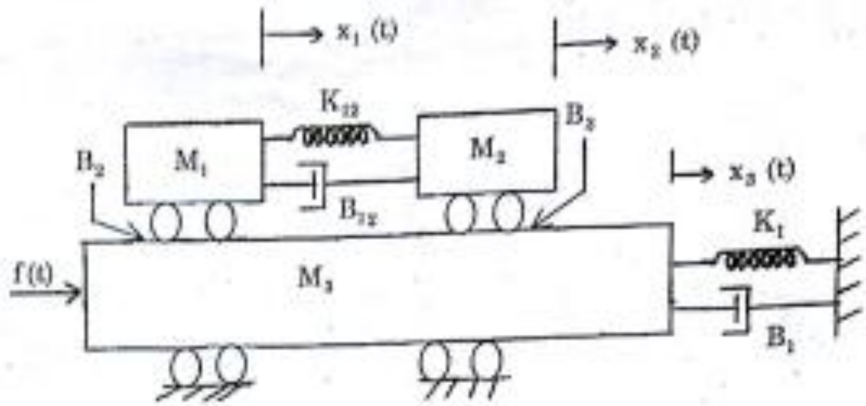


Fig. Q 11 (a)

Or

(b) (i) Derive the transfer function of AC servomotor. (8)

(ii) Construct a block diagram for the simple electrical network shown in Fig. Q 11 (b) (ii) and hence, obtain the signal flow graph and the transfer function $\frac{E_0(s)}{E_i(s)}$. (8)

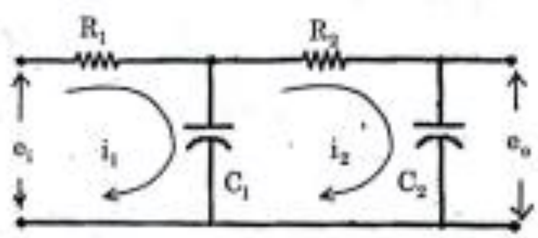


Fig. Q 11 (b) (ii)

12. (a) Draw the root locus for a system is given by $G(s) = \frac{K(s+1)}{s(s^2+5s+20)}$. (16)

Or

(b) (i) The overall transfer function of a control system is given by $\frac{C(s)}{R(s)} = \frac{16}{(s^2+1.6s+16)}$. It is desired that the damping ratio be 0.8. Determine the derivative rate feedback constant K_t and compare rise time, peak time, maximum overshoot and steady state error for unit ramp input function without and with derivative feedback control. (10)

(ii) Compare P, I and D controller.

13. (a) The open loop transfer function of a unity feedback system is given by $G(s) = \frac{1}{s(s+1)(2s+1)}$. Sketch the polar plot and determine the gain margin and phase margin. (16)

Or

(b) Draw the Bode plot for the transfer function $G(s) = \frac{1}{s(s^2+3s+5)}$. Determine the gain margin and phase margin. (16)

14. (a) (i) Determine the range of values of K for which the system described by the following characteristic equation is stable. (10)

$$s^3 + 3Ks^2 + (K+2)s + 4 = 0.$$

(ii) State and explain Nyquist stability criterion. (6)

Or

(b) Design a lead compensator for a unity feedback system with an open loop transfer function $G(s) = \frac{K}{s(s+1)}$ for the specifications of $K_v = 10\,\text{sec}^{-1}$ and phase margin $\phi_m = 35°$. (16)

15. (a) Obtain the time response of the system described by

$$[\dot{x}(t)] = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 1 \\ -1 \end{bmatrix} u(t)$$

with the initial conditions $\begin{bmatrix} x_1(0) \\ x_2(0) \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$; $y(t) = [0 \quad 1] \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix}$. (16)

Or

(b) Determine whether the system described by the following **state model is** completely controllable and observable (16)

$$[\dot{x}(t)] = \begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix} u(t); \quad y(t) = [1 \quad 0 \quad 0] \begin{bmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \end{bmatrix}.$$

Question Paper Code : 72004

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2017.

Fifth Semester

Electrical and Electronics Engineering

IC 6501 — CONTROL SYSTEMS

(Common to Electronics and Instrumentation Engineering/Instrumentation and Control Engineering)

(Regulations 2013)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Why negative feedback is preferred in closed loop control system?

2. What is block diagram? State its components.

3. Define maximum peak overshoot.

4. Determine type and order of the following system $G(s)H(s) = 10/[S^3(S^2 + 2s + 1)]$

5. What is meant by frequency response?

6. State about Lead-Lag compensation.

7. What is characteristic equation?

8. State Nyquist stability criterion.

9. Draw the block diagram representation of a state model.

10. What is controllability?

PART B — (5 × 16 = 80 marks)

11. (a) Write the differential equations governing the mechanical translational system shown in figure1. Draw the electrical equivalent analogy circuits. (16)

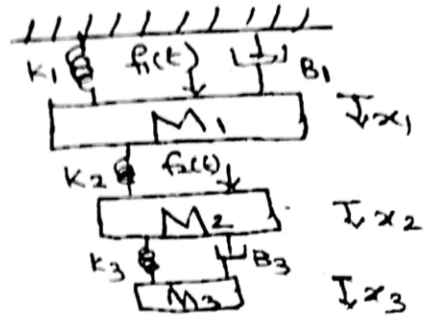


Figure.1.

Or

(b) (i) With its operating principle derive the transfer function of AC servo motor in control system. (12)

(ii) Compare open loop and closed loop control systems. (4)

12. (a) Derive the time response of Undamped and Critically damped second order system for unit step input. (16)

Or

(b) (i) A unity feedback control system has an open loop transfer Function $G(s) = 10/[s(s+2)]$ Find the rise time, peak time, percentage overshoot and settling time for step input of 12 units. (8)

(ii) For servomechanisms, with open loop transfer function given below explain what type of input signal give rise to a steady state error and calculate their values.

(1) $G(s) = [20(s+2)]/s(s+1)(s+3)]$

(2) $G(s) = 10/[(s+2)(s+3)]$. (8)

13. (a) Plot the Bode plot for the following transfer function and determine the phase and gain cross over frequencies. $G(s) = 10/[s(1+0.4s)(1+0.1s)]$. (16)

Or

(b) The open loop function of a unity feedback system is given by $G(s) = 1/[s(1+s)(1+2s)]$. Sketch the polar plot and determine the gain and phase margin. (16)

14. (a) (i) Using Routh criterion, determine the stability of a system representing the characteristic equation $S^4 + 8S^3 + 18S^2 + 16S + 5 = 0$ Comment on location of the roots of the characteristics equation. (6)

(ii) Write down the procedure for designing Lag compensator using Bode plot. (10)

Or

(b) Explain in detail the realization of Lag, Lead and Lag-Lead electrical networks. (16)

15. (a) Check the controllability and observability of the system whose state space representation is given as (16)

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \\ 1 & -2 & 0 \\ 2 & 1 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 10 \\ 1 \\ 0 \end{bmatrix} u \quad y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

Or

(b) (i) What are state variables? Explain the state space formulation with its equation. (8)

(ii) Given that

$A_1 = \begin{bmatrix} \sigma & 0 \\ 0 & \sigma \end{bmatrix}$; $A_2 \begin{bmatrix} 0 & w \\ -w & 0 \end{bmatrix}$; $A = \begin{bmatrix} \sigma & w \\ -w & \sigma \end{bmatrix}$ Compute state transistion matrix. (8)

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Question Paper Code : 41245

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2018

Fifth Semester

Instrumentation and Control Engineering

IC 6501 – CONTROL SYSTEMS

(Common to Electrical and Electronics Engineering/Electronics and Instrumentation Engineering)

(Regulations 2013)

Time : Three Hours

Maximum : 100 Marks

Answer ALL questions

PART – A (10×2=20 Marks)

1. List the characteristics of negative feedback in control system.
2. Write the expression for mason's gain formula.
3. How is a system classified depending on the value of damping ?
4. What is steady state error ?
5. Give the advantages of frequency response analysis.
6. Define corner frequency.
7. Differentiate between gain margin and phase margin.
8. What is dominant pole ?
9. Write the advantages of state space analysis.
10. State the concept of observability.

PART – B

(5×13=65 Marks)

11. a) Write the differential equations governing the mechanical system shown in Fig 11.a. Also draw the force voltage and force current analogous circuit and verify by writing mesh and node equations. **(13)**

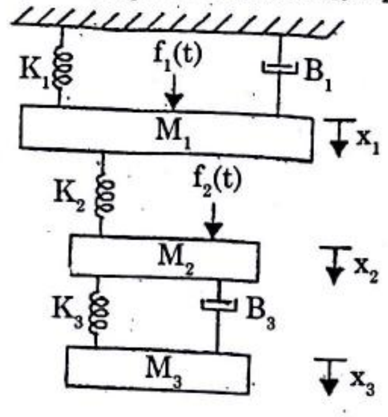

Fig 11. a)

(OR)

b) The block diagram of a closed loop system is shown in Fig 11. b). Using block diagram reduction technique, determine the closed loop transfer function. **(13)**

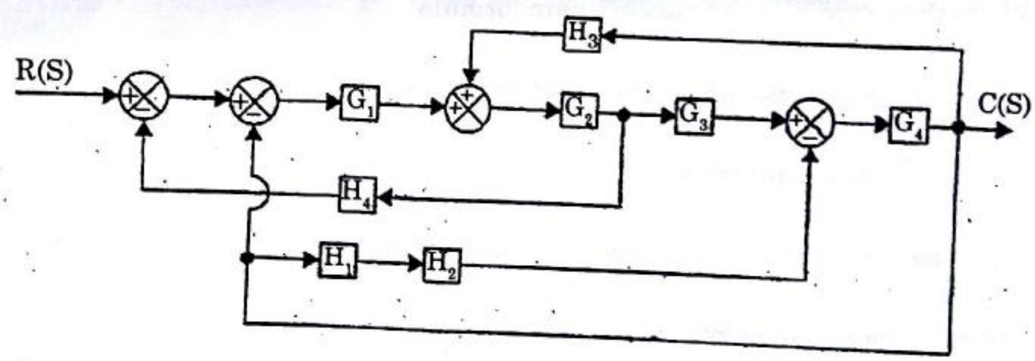

Fig. 11. (b)

12. a) i) Outline the time response of first order system when it is subjected to a unit step input. **(8)**

ii) Determine the response of the unity feedback system whose open loop transfer function is $G(s)=\frac{4}{s(s+5)}$ and when the input is unit step. **(5)**

(OR)

b) i) A unity feedback system has the forward transfer , function

$$G(s) = \frac{K_1(2s+1)}{s(5s+1)(1+s)^2}$$ when the input r(t) = 1 + 6t, determine the

minimum value of K_1 so that the steady error is less than 0.1. **(8)**

ii) Derive the transfer function of PID controller. **(5)**

13. a) Construct the polar plot and determine the gain margin and phase margin of a unity feedback control system whose open loop transfer function is,

$$G(s) = \frac{(1+0.2s)(1+0.025s)}{s^3(1+0.005s)(1+0.001s)}.$$ **(13)**

(OR)

b) Draw the bode diagram for the following transfer function,

$$G(s) = \frac{75(1+0.2s)}{s(s^2+16+100)}$$ **(13)**

14. a) i) Use the routh stability criterion, determine the range of K for stability of unity feedback system whose open loop transfer function is

$$G(s) = \frac{K}{s(s+1)(s+2)}.$$ **(10)**

ii) State Routh stability criterion. **(3)**

(OR)

b) Design a lead compensator for a unity feedback system with open loop transfer function, $G(s) = \frac{K}{s(s+1)(s+5)}$ to satisfy the following specifications

i) Velocity error constant, $K_v \geq 50$

ii) Phase margin $\geq$ 20 degrees. **(13)**

15. a) Determine the canonical state model of the system whose transfer function is

$$T(s) = \frac{2(s+5)}{(s+2)(s+3)(s+4)}.$$ **(13)**

(OR)

b) Consider a linear system described by the following transfer function, $\frac{Y(s)}{U(s)} = \frac{10}{s(s+1)(s+2)}$. Design a feedback controller with a state feedback so that the closed loop poles are placed at $-2, -1 \pm j1$. **(13)**

PART – C **(1×15=15 Marks)**

16. a) A unity feedback control system has an open loop transfer function,

$G(s) = \frac{k}{s(s^2+4s+13)}$. Sketch the Root Locus. **(15)**

(OR)

b) Construct the Nyquist plot for a system whose open loop transfer function is given by $G(s)H(s) = \frac{K(1+s)^2}{s^3}$, Find the range of K for stability. **(15)**

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Question Paper Code : 50714

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2017

Fifth Semester

Electronics and Instrumentation Engineering

IC6501 – CONTROL SYSTEMS

(Common to Electrical and Electronics Engineering/Instrumentation and Control Engineering)

(Regulations 2013)

ime : Three Hours

Maximum : 100 Marks

Codes / Tables / Charts to be permitted, if any may be indicated

Answer ALL questions

PART – A (10×2=20 Marks)

1. Define open loop and closed loop control system.
2. What are the basic elements used for modeling mechanical translational system ?
3. Distinguish between type and order of a system.
4. What is the effect on system performance when a proportional controller is introduced in a system ?
5. List out the different frequency domain specifications.
6. Give the need for lag/lag-lead compensation.
7. What are the necessary conditions for stability ?
8. What are the effects adding open loop poles and zero on the nature of the root locus and on system ?
9. Write the homogeneous and nonhomogeneous state equation.
10. Define state trajectory.

PART – B (5×13=65 Marks)

11. a) Find the transfer function $\frac{y_2(s)}{f(s)}$.

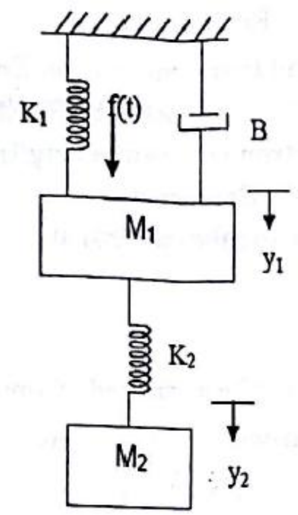

Fig. 11 a

(OR)

b) Find the overall gain C(S) / R(S) for the signal flow graph shown in Fig. 11 b.

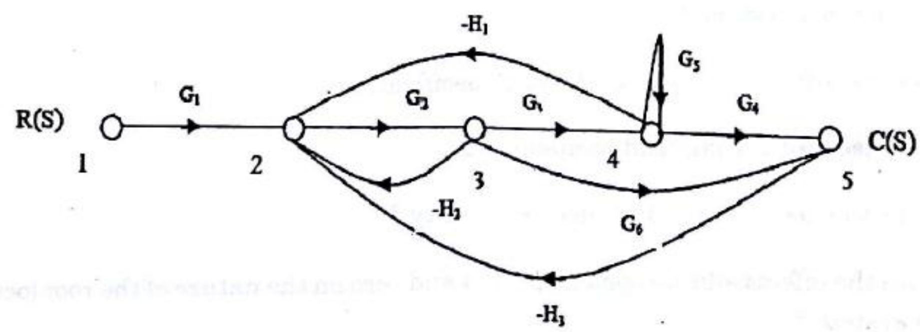

Fig. 11 b

12. a) Derive the expressions for second order system for under damped case and when the input is unit step.

(OR)

b) Find the static error coefficients for a system whose transfer function is, G (s). H (s) = 10/s (1 + s) (1 + 2s). And also find the steady state error for $r(t) = 1 + t + t_{2/2}$.

13. a) Sketch the Bode plot and hence find Gain cross over frequency, Phase cross over Frequency, Gain margin and Phase margin for the function

$$G(s) = \frac{10(s+3)}{s(s+2)(s^2+4s+100)}.$$

(OR)

b) Sketch the polar plot for the following transfer function and find Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin for G (s) = 400/s (s+ 2) (s + 10).

14. a) A unity feedback control system has an open loop transfer function $G(s) = K(s+9) / s(s^2+4s+11)$. Sketch the root locus.

(OR)

b) Determine the stability of closed loop system by Nyquist stability criterion, whose open loop transfer function is given by, G (s). H (s) = (s + 2) / (s+ 1) (s – 1).

15. a) Explain the concepts of controllability and observability.

(OR)

b) Obtain the complete solution of nonhomogeneous state equation using time domain method.

PART – C (1×15=15 Marks)

16. a) For the given system, G (s) = K / s (s + 1) (s + 2), design a suitable lag-lead compensator to give, velocity error constant = 10 sec-1, phase margin = 50°, gain margin ≥ 10 dB.

(OR)

b) Realize the basic compensators using electrical network and obtain the transfer function.