Chettinad College of Engineering & Technology
Approved by AICTE-New Delhi and Affiliated to Anna University-Chennai.

Academic Year 2024-25

Question Bank

Year/Semester: II/ III **Date: 12/08/2024**	**Department : ECE** **Subject Code/Title : EC3351 / Control Systems** **Faculty Name : Ms.D.Ragavi**	**Unit :** I,II,III,IV,V **Section : Part A/B/C**

UNIT I

SYSTEMS COMPONENTS AND THEIR REPRESENTATION

Part A:

1. **What is control system? (R)**

   A system consists of a number of components connected together to perform a 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? (R)**

   The two major types of control system are open loop and closed loop.

3. **Define open loop control system. (R)**

   The control system in which the output quantity has no effect upon the input quantity is called open loop control system. This means that he output is not feedback to the input for correction.

4. **Define closed loop control system.(R)**

   The control system in which the output has an effect upon the input quantity so as to maintain the desired output value is called closed loop control system.

5. **What are the components of feedback control system? (R)**

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

6. **Distinguish between open loop and closed loop system.(AZ)**

1. Inaccurate	Accurate
2. Simple and economical	Complex and costlier
3. The changes in output due to external disturbance are not corrected	The changes in output due to external disturbances are corrected automatically

4. They are generally stable	Great efforts are needed to design a stable system

7. Why negative feedback is invariably preferred in closed loop system? (AZ)

The negative feedback results in better stability in steady state and rejects any disturbance signals.

8. Define transfer function. (R)

The transfer function of a system is defined as the ratio of the Laplace transform of output to Laplace transform of input with zero initial conditions.

9. What are the basic elements used for modeling mechanical translational system. (R)

Mass, spring and dashpot.

10. What are the basic elements used for modeling mechanical rotational system? (R)

Moment of inertia J, dashpot with rotational frictional coefficient B and torsional spring with stiffness K.

11. Write the force balance equation of an ideal mass element. (A)

$F = M\, d^2x/dt^2$

12. Write the force balance equation of ideal dashpot element. (A)

$F = B\, dx/dt$

13. Write the force balance equation of ideal spring element. (A)

$F = kx$

14. Name two types of electrical analogous for mechanical system. (R)

The two types of analogies for the mechanical system a Force voltage and force current analogy.

15. Write the analogous electrical element's in force voltage analogy for the elements of mechanical translational system. (A)

- Force-voltage e
- Velocity v-currents
- Displacement x-charge q
- Frictional coefficient B-Resistance R
- Mass M-Inductance L
- Stiffness K-Inverse of capacitance 1/C

16. Write the analogous electrical elements in force current analogy for the elements of mechanical translational system. (A)

- Force-current i
- Velocity v-voltage v
- Displacement x-flux φ
- Frictional coefficient B-conductance 1/R
- Mass M- capacitance C
- Stiffness K-Inverse of inductance 1/L

17. What is block diagram? (R)

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 block, branch point and summing point.

18. What is the basis for framing the rules of block diagram reduction technique? (R)

The rules for block diagram reduction technique are framed such that any modification made on the diagram does not alter the input output relation.

19. What is a signal flow graph? (R)

A signal flow graph is a diagram that represents a set of simultaneous algebraic equations. By taking L. Į the time domain differential equations governing a control system can be transferred to a set of algebraic equations in s-domain.

20. What is transmittance? (R)

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

21. What is sink and source? (R)

Source is the input node in the sig al for graph and it has only outgoing branches. Sink is an output node in the signal flow graph and it has only incoming branches.

22. Define non touching loop. (R)

The loops are said to be no touching if they do not have common nodes.

23. Write Masons Gain formula. (A)

Masons Gain formula states that the overall gain of the system is

$T = 1/\Delta \Sigma P_k \Delta_k$

k- Forward path in the signal flow graph

P_k -Forward path gain of k^{th} forward path

Δ = 1-[sum of individual loop gains +[sum of gain products of all possible combinations of two non touching loops]-[sum of gain products of all possible combinations of three non touching loops]+...

$\Delta_{k} = \Delta$ for that part of the graph which is not touching kth forward path.

24. What is servomechanism? (R)

The servomechanism is a feedback control system, in which the output is mechanical position (or time derivatives of position velocity and acceleration).

25. What is servomotor? (R)

The motors used in automatic control systems or in servomechanism are called servomotors. They are used to convert electrical signal into angular motion.

26. What is synchro? R

A synchro is a device used to convert an angular motion to an electrical signal or vice versa.

27. Why negative feedback is invariably preferred in closed loop system? (AZ)

The negative feedback results in better stability in steady state and rejects any disturbance signals.

28. What are the basic properties of signal flow graph? (R)

The basic properties of signal flow graph are

- Signal flow graph is applicable to linear systems.
- It consists of nodes and branches.
- A node adds the signal of all incoming branches and transmits this sum to all
- outgoing branches.
- Signals travel along branches only in the marked direction and is multiplied by
- the gain of the branch.
- The algebraic equations must be in the form of cause and effect relationship.

29. Name any two dynamic models used to represent control systems. (R)

- Translational model
- Rotational model

30. Write the analogous electrical elements in force voltage analogy and force (A) current analogy for the elements of mechanical translational and rotational system.

Translational/Rotational System	Force Voltage Analogy	Force Current Analogy
Force, f or Torque, T	Voltage, e	current, i
Velocity, V or Angular Velocity, ω	current, i	Voltage, e

Displacement, x or θ charge , q flux, Φ

Angular Displacement

Frictional coefficient, B Resistance

or Frictional coefficient, B Mass, M or Moment of Inertia, J inductance, L capacitance C

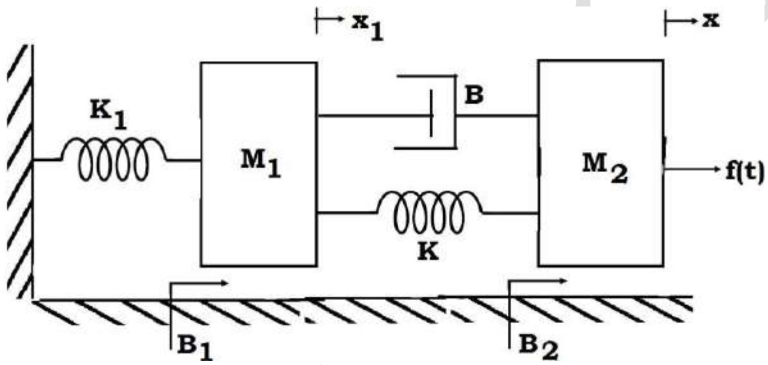
Stiffness, K or Stiffness, K Inverse of capacitance 1/C Inverse of inductance, 1/L

Newton"s second law Kirchhoff"s voltage law Kirchhoff"s current law.

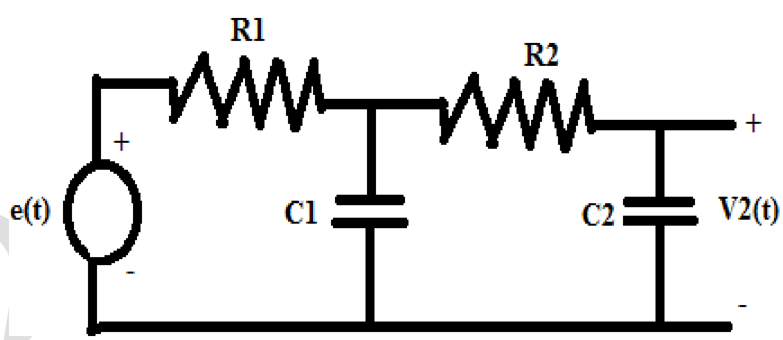
Part B:

1. Inspect the given system and derive the differential equations governing the system **(E)**

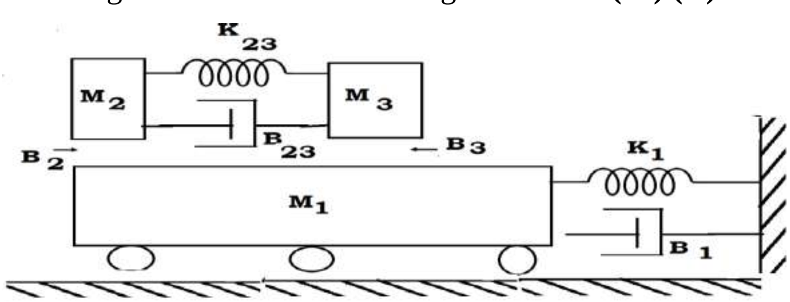
(i) Mechanical System **(7)**



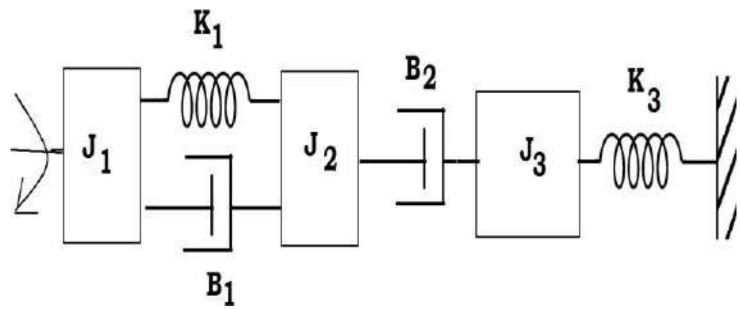
(ii) Electrical System **(6)**



2. Write the differential equations governing the mechanical system shown in figure. Draw the force voltage and force current analogous circuits.**(13) (C)**



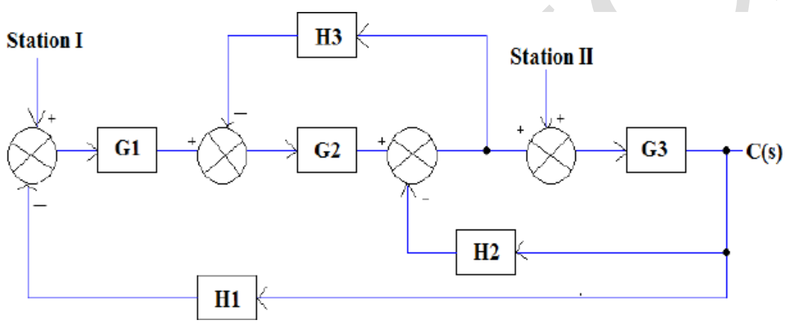
3. Give the Torque voltage and torque current analogous circuit for the given system. **(13) (C)**



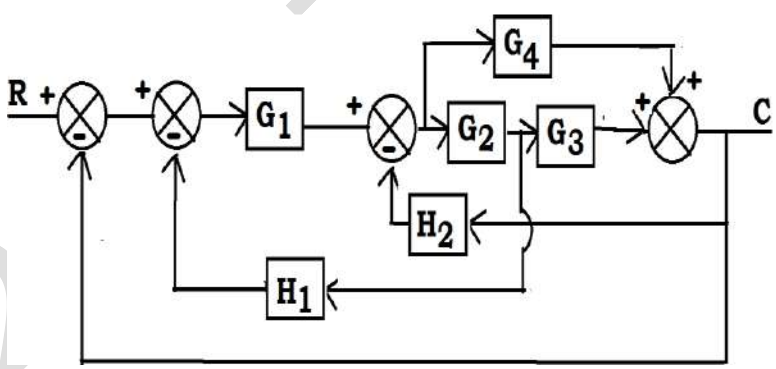
4. (i) State the block diagram reduction rules with example**. (7) (U)**

(ii) Mention in detail about any five terminologies used in signal flow graph**.(6) (R)**

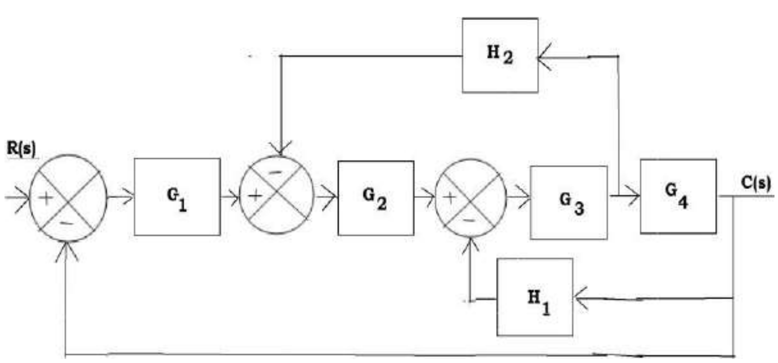
5. Evaluate the transfer function for the given system when the input R is (i)at station I (ii) at station II**.(13) (E)**



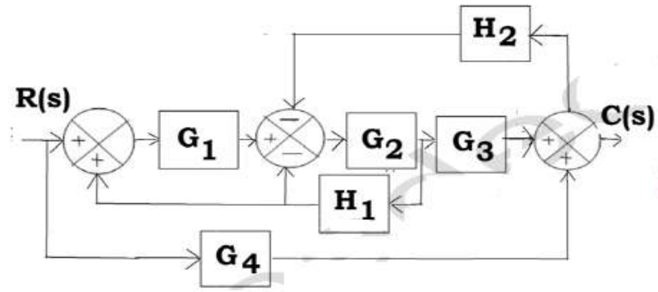
6. Analyze the given block diagram to derive the transfer function**. (13) (AZ)**



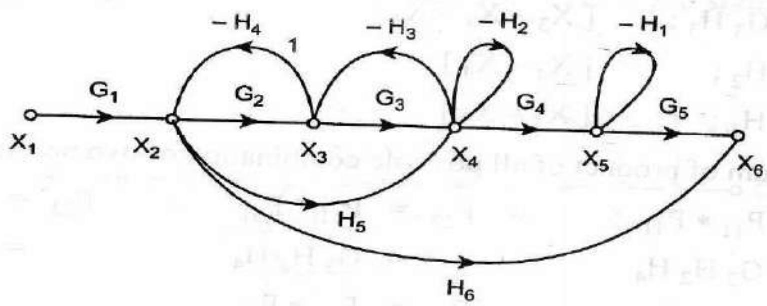
7. Examine the given system and reduce it to determine the transfer function **(13) (U)**



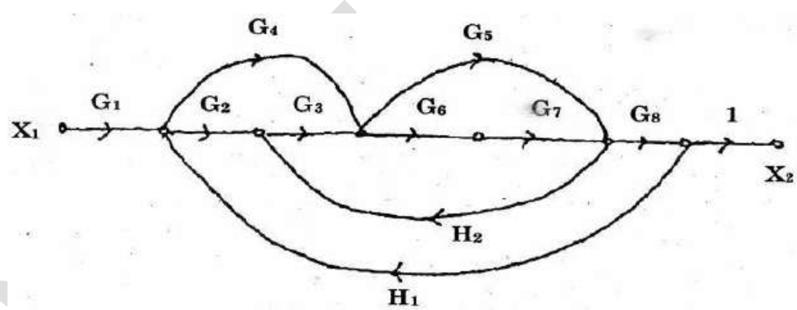
8. Utilize block diagram reduction rules to calculate the transfer function of the given system? **(13) (E)**



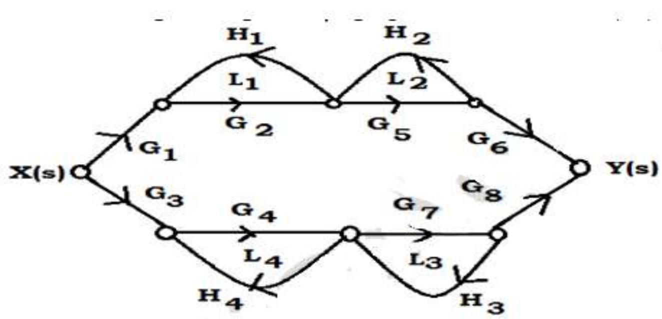
9. Illustrate Masons formula to derive the transfer function of a given SFG **.(13) (C)**



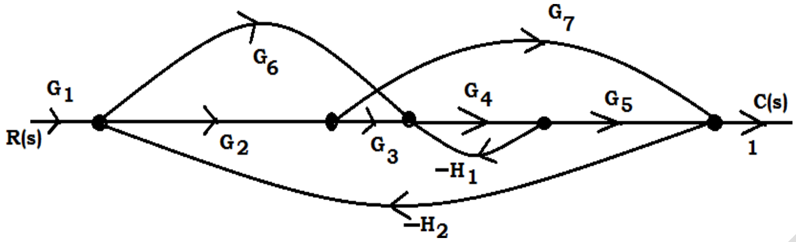
10. Demonstrate the usage of Mason's gain formula to derive the transfer function of the given graph**.(13) (C)**



11. Apply Masons gain formula to determine the transfer function of the given signal flow graph**.(13) (A)**



12. Obtain the closed loop transfer function of the system from the given Signal Flow graph.**(13) (A)**



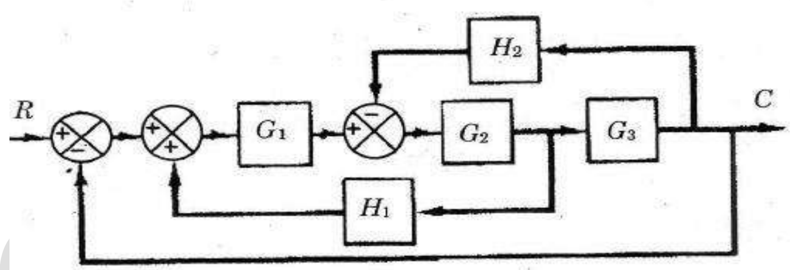
13. (i) Explain with a neat block diagram explain the working of field controlled DC motor as a control system.**(7) (U)**

(ii) Explain the features of closed loop control system.**(6) (U)**

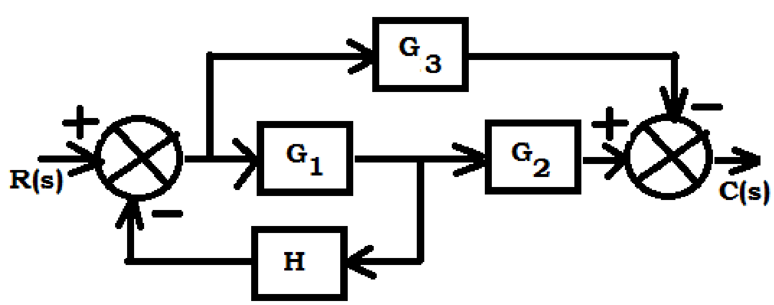
14. Narrate about the servomotor used in control system **(13) (R)**

Part C:

1. Convert the block diagram shown in figure to signal flow graph and find the transfer function using mason's gain formula. Verify with the block diagram approach.**(15) (C)**



2. Simplify the following diagram using block diagram reduction method. Also derive the transfer function of the same using signal flow graph.**(15) (A)**



3. Describe with a neat block diagram the working of Armature controlled DC motor as a control system.**(15) (U)**
4. Summarize about the construction, principle and usage of synchros in control systems**.(15) (U)**

UNIT II

TIME RESPONSE ANALYSIS

Part A:

1. **What is transient response & steady state response of a system? (R)**

   - The transient response is the response of the system when the system changes from one state to another.
   - The steady state response is the response of the system when it approaches infinity.

2. **What is the difference between type & order of a system?**

   Type number of a system indicates the number of poles at the origin whereas 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. (R)**

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

4. **List the time domain specifications (or) what are the time domain specifications? (U)**

   The time domain specifications are

   - Delay time
   - Rise time
   - Peak time
   - Peak overshoot

5. **Define Delay time, Rise time, Peak time. (R)**

   Delay time: The time taken for response to reach 50% of final value for the very first time isdelay time.

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

   Peak time: The time taken for the response to reach the peak value for the very first time is peak time.

6. **Define peak overshoot. (R)**

   Peak overshoot is defined as the ratio of maximum peak value to the final value, where the maximum peak value is measured from the final value.

7. **Define Settling time. (R)**

Settling time is defined as the time taken by the response to reach and stay within specified error.

8. What is the significance of integral controller and derivative controller in a PID controller? (U)

- The Proportional controller stabilizes the gain but produces a steady state error.
- The Integral control reduces or eliminates the steady state error.

9. Why derivative controller is not used in control systems? (AZ)

- 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.
- It is sensitive to noise signal and amplifies the noise.

10. What is the drawback of static coefficients? (R)

The main drawback of static coefficient is that it does not show the variation of error with time and input should be standard input.

11. What are the main advantages of generalized error coefficients? (R)

- Steady state is function of time.
- Steady state can be determined from any type of input.

12. What are the standard test signals used in control systems? (R)

The commonly used test input signals in control system are impulse, step, ramp, parabolicand sinusoidal signals.

13. What are the advantages & disadvantages of proportional controller? (R)

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

Advantage:

- Improves disturbance signal rejection
- Improves stability of the system
- Increases the loop gain of the system

14 What is the effect of PD controller on system performance? (AZ)

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

15. What is the effect of PI controller on the system performance? (AZ)

The PI controller increases the order of the system by one, which results in reducing thesteady state error. But the system becomes less stable than the original system.

16. How a control system is classified depending on the value of damping? (AZ)

- ξ=0; Undamped system
- 0< ξ<1; Under damped system
- ξ=1; Critically damped system
- ξ>1; Over damped system

17. What is steady state error? (R)

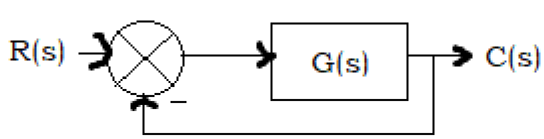
It is the difference between desired output & actual output of the system as t tends to infinity.

Part B:

1. The unity feedback system is characterized by an open loop transfer function $(s) = \frac{K}{s(s+10)}$. Examine the gain K , so that $s(s+10)$ the system will have a damping ratio of 0.5 for this value of K. Examine settling time, peak overshoot and peak time for a unit step input.**(13) (E)**
2. Summarize and derive the time domain specifications of a second order system subjected to a step input. .**(13) (R)**

   (i) Name the various standard test signals? Draw the characteristics diagram and obtain the mathematical representation of all**. (7) (R)**

   (ii) Write the response of undamped second order system for unit step input**.(6) (R)**
3. (i) Outline the response of unity feedback system whose open loop transfer function is $G(s)$ =4/S(S+5) and when the input $s(s+5)$ is unit step**.(7)**



   (ii) Write the response of critically damped second order system for unit step input.(6)
4. With a step input of 12 units, for a unity feedback control system which has an open loop transfer function $G(s)$ = 10/S(S+2).Find .**(13) (R)**

(i) Rise time **(3)**

(ii) Percentage overshoot **(4)**

(iii) Peak time**(3)**

(iv) Settling time **(3)**

5. The open loop transfer function of a unity feedback system is given by G(s) =K/ s(sT+1), where K and T are positive constant. By what factor should the amplifier gain K be reduced, so that the peak overshoot of unit step response of the system is reduced from 75% to 25%.(.**(13) (A)**

6. A UFB is characterized by the following open loop transfer function (s) = (0.4s+1)/(s+0.6). Develop its transient response for unit step input and sketch the response and also find the maximum overshoot and the corresponding peak time. .**(13) (C)**

7. The forward transfer function (s) =K(2S+1)/S(5S+1)$(1+S)^2$.The input r(t) = 1 + 6t is applied to the system. Determine the minimum value of K if the steady state error is to be less than 0.1.**(13) (E)**

8. Evaluate the expression for steady state error for type 0, type1 and type 2 system for unit step, unit ramp and unit parabola inputs. .**(13) (E)**

9. (i) Find the static error constants for a unity feedback system having a forward path transfer function (s) =50/ (s + 10.**(13) (AZ)**

10. (ii) For the above transfer function, interpret the steady state errors of the system for the input r(t) = 1 + 2t + t2.**(13) (E)**

11. (i) For a unity feedback control system, the open loop transfer function is $G(s)$ = 10(S+2)/ S^2 (S+1) , construct the The position, velocity, acceleration error constants(7)

(ii) The steady state error when(s) = (3/S) − (2/S^2) + (1/3S^3). **(6) (C)**

12. With suitable block diagrams and equations, examine the following types of controllers employed in control systems .**(13) (E)**

(i) Proportional plus integral control **(4)**

(ii) Proportional plus derivative control **(4)**

(iii) PID Controller **(5)**

13. For the system with $G(s)$ = 5/ (s+5).Calculate .**(13) (E)**

(i) Generalized error coefficients **(7)**

(ii) Steady state error. Assume r(t) = 6 + 5t (6)

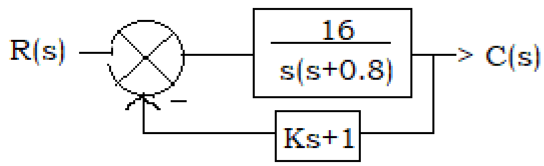
14. What type of input should be applied to the below transfer function to get a constant steady stat error. Solve for its value .**(13) (A)**

(i) $G(s)$ =20(s+2)/ s(s+1)(s+3) **(7)**

(ii) $G(s)$ =10/(s+2)(s+3) **(6)**

Part C:

1. The positional control system is shown below .**(15) (E)**



(i) Formulate the response c(t) to unit step input given that 0.5.**(8)**

(ii) Estimate rise time, peak time, maximum overshoot and settling time.**(7)**

2. Measurements conducted on a servo mechanism show that the system response to be $(t) = 1 + 0.2e-60t - 1.2e-10t$ when subjected to a unit step input. .**(15) (AZ)**

(i) Obtain an expression for closed loop transfer function .**(5)**

(ii) Evaluate the undamped natural frequency and damping ratio.**(10)**

3. Consider a UFB with a closed loop transfer function $C(s)/ R(s) = Ks+b/ s2 +as+b$ Determine the open loop transfer function G(s). Prove that the steady state error with unit ramp input is given by $(a-K)$/b. (.**(15) (A)**

4. Summarize the effect of PI, PD and PID controller on the system performance.**(15) (R)**

UNIT III
FREQUENCY RESPONSE AND SYSTEM ANALYSIS
Part A:

1. List out the different frequency domain specifications. (R)

- The frequency domain specifications are
- Resonant peak, Resonant frequency, Bandwidth, Cut-off rate, Gain Margin, Phase Margin

2. Define resonant Peak (M_r) & resonant frequency (ω_r). (R)

- The maximum value of the magnitude of closed loop transfer function is called Resonant Peak.
- The frequency at which resonant peak occurs is called resonant frequency.

3. What is Bandwidth? (R)

The Bandwidth is the range of frequencies for which the system gain is more than 3 dB. The bandwidth is a measure of the ability of a feedback system to reproduce the input signal noise rejection characteristics and rise time.

4. Define Cut off rate. (R)

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.

5. Define Gain Margin. (R)

The Gain Margin, Kg is defined as the reciprocal of the magnitude of the open loop transfer function at phase cross over frequency.

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

6. Define Phase cross over frequency. (R)

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

7. What is Phase margin? (U)

The Phase margin is the amount of additional phase lag at the gain cross over frequency required to bring system to the verge of instability.

$$\text{Phase margin, } \gamma = 180^0 + \varphi_{gc}$$

8. Define Gain cross over frequency. (R)

The Gain cross over frequency, $\omega_{gc,}$ is the frequency at which the magnitude of the open loop transfer function is unity.

9. What is Bode plot? (AZ)

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 Δ. The other is a plot of the phase angle of a sinusoidal function versus log ω.

10. Define Corner frequency. (R)

The frequency at which the two asymptotic meet in a magnitude plot is called Corner frequency.

11. What are M circles? (AZ)

The magnitude of closed loop transfer function with unit feedback can be shown for every value of M. These circles are called M circles.

12. What is Nichols chart? (AZ)

The chart consisting of M & N loci in the log magnitude versus phase diagram is called Nichols chart.

13. List the advantages of Nichols chart? (U)

The advantages are:

- It is used to find the closed loop frequency response from open loop frequency response.
- Frequency domain specifications can be determined from Nichols chart.
- The gain of the system can be adjusted to satisfy the given specification.

14. How closed loop frequency response is determined from the open loop frequency using M& N circles? (C)

The G(jω) locus or polar plot of open loop system is sketched on the standard M and N circles chart. The meeting point of M circle with G(jω) locus gives the magnitude of closed loop system. The meeting point of G(jω) locus with N-circle gives the value of phase of closed loop system.

15. Express the uses of lead compensator? (U)

- Speeds up the transient response
- Increases the margin of stability of a system
- Increases the system error constant to a limited extent.

16. What is a compensator? (AZ)

A device inserted into the system for the purpose of satisfying the specifications is called asa compensator.

Part B:

1. Given G(s) = $(s+2)(s+8)$.Draw the Bode plot and find K for the following two cases: Gain margin equal to 6dB and Phase margin equal to 45°. **(13) (A)**
2. An UFB system has G(s) =$K/ (s+2)(s+8)$.Design a Lag compensator for the following specification e_{ss} for ramp input ≤ 0.125 and percentage overshoot ≤ 16%. **(13) (C)**
3. The open loop transfer function of a unity feedback control system is G(s) =$k/ s(s+3)(s+6)$.Illustrate a suitable lag-lead compensator so as to meet the following specifications static energy velocity error constant K_v =80 and phase margin ≥35◦ **(13) (C)**
4. Consider a unity feedback system having an open loop transfer function G(S)=K/S (1+ 0.5S)(1+4S).Outline the polar plot and determine the value of K so that Gain margin is 20dBand phase margin is 30°. **(13) (U)**
5. A unity feedback control system has G(s) = $ks^2/(1+0.2s)(1+0.02s)$, Find the Bode plot. Find K when GCOF = 5rad/sec. **(13) (E)**
6. Sketch the polar plot and find the gain and phase margin of a control system has G(s) =1/ $s2$ $(s+1)(1+2s)$ with unity feedback. **(13) (E)**
7. Discuss a suitable lead compensator for a system with G(S) =$k/ (s+8)$ to meet the specifications. **(13) (R)**

   (i) Kv ≥10 sec -1 **(5)**

   (ii) Natural frequency,w_n=12 rad/sec **(5)**

   (iii) % peak overshoot,M_p=9.5% . **(3)**
8. A Unity feedback system has an open loop transfer function,G(s) = $k/ s(1+2s)$. Select a suitable lag compensator so that phase margin is 40° and the steady state error for ramp input is less than or equal to 0.2. **(13) (AZ)**
9. Conclude a Lead Compensator for a Unity feedback System with Open loop transfer

function G(S) =K/ S(S+1)(S+5) to Satisfy the following Specifications. **(13) (A)**

(i) Velocity error Constant, $K_v \geq 50$ **(7)**

(ii) Phase Margin is ≥ 20 degrees. **(6)**

10. Analyze and discuss briefly about the lag and lag-lead compensators with examples. **(13) (AZ)**

11. Develop the detailed notes on following: **(C) (13)**

(i) Frequency domain specification. **(3)**

(ii) Derive any two frequency domain specification parameters. **(10)**

12. For the$G$(S) = 5(1+2S)/ (1+4S)(1+0.25S),Show the value of phase and gain margin using bode plot. **(13) (A)**

13. Report the value of gain and phase cross over frequencies for the following function using bode plot. G(S) =10/ S(1+0.4S)(1+0.1S) **(13) (U)**

14. (i) Write short notes on series compensation**.(3) (R)**

(ii) Write down the procedure for designing lead compensatorusing bode plot**.(10) (R)**

Part C:

1. Consider a Unity feedback system has an open loop transfer function, G(s) = K/ s(1+0.2s)(1+0.05s). Apply the polar plot and determine the value of k so that **(15) (A)**

(i) Gain margin is 18db. **(7)**

(ii) Phase margin is 60 degrees. **(8)**

Unity feedback control system having G(S) =k/ S(S+4)(s+80).Design a lag compensator such that the closed loop system will satisfy the following specification.**(15) (E)**

(i) Phase margin = 33 degrees **(7)**

(ii) (ii) K_v=30. **(8)**

2. Sketch the Polar plot for G(S) =1/ (s+1)(1+2s) and determine the gain margin and phase margin. **(15) (E)**

3. Evaluate the stability of the unity feedback system G(S) = 20/S(1+3S)(1+4S) using bode plot. **(15) (E)**

UNIT IV
CONCEPTS OF STABILITY ANALYSIS
Part A:

1. State Nyquist stability criterion. (R)

If the Nyquist plot of the open loop transfer function G(s) corresponding to the Nyquist control in the S-plane encircles the critical point –1+j0 in the counter clockwise direction as many times as the number of right half S-plane poles of G(s), the closed loop system is stable.

2. Define Relative stability. (U)

Relative stability is the degree of closeness of the system, it is an indication of strength ordegree of stability.

3. What are the two segments of Nyquist contour? (R)

- A finite line segment C1 along the imaginary axis.
- An arc C2 of infinite radius.

4. What are root loci? (AZ)

The path taken by the roots of the open loop transfer function when the loop gain is varied from 0 to 1 are called root loci.

5. What is a dominant pole?

The dominant pole is a complex conjugate pair which decides the transient response of thesystem.

6. What are the main significances of root locus? (AZ)

- The main root locus technique is used for stability analysis.
- Using root locus technique the range of values of K, for a stable system can be determined.

7. What are the effects of adding a zero to a system? (AZ)

Adding a zero to a system increases peak overshoot appreciably.

8. Define stability. (R)

A linear relaxed system is said to have BIBO stability if every bounded input results in abounded output.

9. What is the relationship between Stability and coefficient of characteristic polynomial? (AZ)

- If the coefficient of characteristic polynomial are negative or zero, then some of the rootslie on the negative half of the S-plane. Hence the system is unstable.
- If the coefficients of the Characteristic polynomials are positive and if no coefficient

is zero then there is a possibility of the system to be stable provided all the roots are lying on the left half of the S-plane.

10. What is Routh stability criterion? (R)

- Routh criterion states that the necessary and sufficient condition for stability is that all of the elements in the first column of the routh array is 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 routh array corresponds to the number of roots of characteristic equation in the right half of the S-plane.

11. What is limitedly stable system? (R)

For a bounded input signal if the output has constant amplitude oscillations, then the system may be stable or unstable under some limited constraints such a system is called limitedly stable system.

12. What is a principle of argument? (R)

- The principles of arguments states that let F(S) are analytic function and if an arbitrary closed contour in a clockwise direction is chosen in the S-plane so that F(S) is analytic at every point of the contour.
- Then the corresponding F(S) plane contour mapped in the F(S) plane will encircle the origin N times in the anti clockwise direction, where N is the difference between number of poles and zeros of F(S) that are encircled by the chosen closed contour in the S plane.

13. What are break away and break in points? (AZ)

At break away point the root locus breaks from the real axis to enter into the complex plane. At break in point the root locus enters the real axis from the complex plane. To find the break away or break in points, form an equation for K from the characteristic equation and differentiate the equation of K with respect to s. Then find the roots of the equation dK/dS = 0. The roots of dK/dS = 0 are break away or break in points provided for this value of root the gain K should be positive and real.

14. What are asymptotes? How will you find angle of asymptotes? (E)

Asymptotes are the straight lines which are parallel to root locus going to infinity and meet the root locus at infinity.

Angles of asymptotes = ±180°(2q + 1)/(n-m) q= 0,1,2, …….(n-m) n-number of poles; m-number of zeros.

15. How will you find the root locus on real axis? (AZ)

- To find the root loci on real axis, choose the test point on real axis. If the total number of poles and zeros on the real axis to the right of this test point is odd number then the test point lie onthe root locus.
- If it is even then the test point does not lie on the root locus.

16. How the roots of characteristic equation are related to stability? (AZ)

- If the root of characteristic equation has positive real part then the impulse response of the system is not bounded.
- Hence the system will be unstable. If the root has negative real parts thenthe impulse response is bounded. Hence the system will be stable.

17. What is the necessary condition for stability? (R)

- The necessary condition for stability is that all the coefficients of the characteristic polynomial be positive.
- The necessary and sufficient condition for stability is that all of the elements in the first column of the routh array should be positive.

18. What are the requirements for BIBO Stability? (R)

The requirement of the BIBO stability is that the absolute integral of the impulse response of the system should take only the finite value.

Part B:

1. Using Routh criterion, Investigate the stability of a unity feedback control system whose open-loop transfer function is given by $G(s)=Ke^{-s}/S(S^2+5S+9)$. **(13) (E)**

2. Discuss the stability of a system with characteristics equation $9S^5 - 20S^4 + 10S^3 - S^2 - 9S - 10 = 0$ using Routh Hurwitz criterion. **(13) (U)**

3. Generate the range of K for stability of unity feedback system whose OLTF is $G(s) = k/(s+1)(s+2)$ using RH criterion. **(13) (C)**

4. Identify the range of values of K for stability of unity feedback system, using Routh stability Criterion whose Transfer function $G(S) = K/(S+2)(S+4)(S^2+6S+25)$. **(13) (A)**

5. Sketch the root locus of the system whose open loop transfer function is $(s) = K/S(S+2)(S+4)$. Find the value of K so that the damping ratio of the closed loop system is 0.5**. (13) (E)**

6. (i) Express the mathematical preliminaries for Nyquist stability criterion**. (6) (R)**

(ii) Explain the procedure for Nyquist Stability Criterion. **(7) (U)**

7. Interpret Routh array and determine the stability of the system whose characteristic equation is S5 + S4 + 2S3 + 2S2 + 3S + 5 = 0. Comment on the location of the roots of Characteristic equation**. (13) (E)**

8. Label the Root Locus of the system whose open loop transfer function is(s) = K/ S(s2 +6s+10) . Determine the Value of K for which the given system is stable**.(13) (E)**

9. Demonstrate the Nyquist plot for a system, whose Open loop transfer function is given by G(S) H(S) = $K(1+S)^2$/ S3.Find the range of K for stability.(13) **(A)**

10. Analyze the Nyquist plot for the System whose open loop transfer function is G(s) H(s) = K / S(S+2)(S+10). Determine the range of K for which the closed loop System is stable. **(13) (AZ)**

11. Using Routh Hurwitz criterion determine the stability of a system representing the characteristic equation S6 + S5 + 3S4 + 3S3 + 3S2 + 2S + 1 = 0 and comment on location of the roots of the characteristic equation. **(13) (A)**

12. (i) Examine the open loop gain for a specified damping of the dominant roots. **(7) (E)**

(ii) Point out the concepts BIBO stability. **(6) (R)**

13. Explain briefly about the steps to be followed to construct am root locus plot of a given transfer function. **(13) (U)**

14. (i) Write detailed notes on relative stability with its roots of S-plane**. (7) (R)**

(ii) State and explain about different cases of Routh Hurwitz criterion. **(6) (R)**

Part C:

1. A unity feedback control system has an open loop transfer function G(S) = K/ (S2+4S+13) . Determine the location of poles using root locus. **(15) (E)**

2. Construct R-H criterion for the characteristic equation S7 + 5S6 + 9S5 + 9S4 + 4S3 + 20s2 + 36S + 36 = 0. Find the location of roots on S-plane and hence the stability of the system. **(15) (C)**

3. The open loop transfer function of a unity feedback system is given by G(S) = (S+9) / (S2+4S+11).Sketch the root locus of the system and also evaluate the system stability with respect to their location of poles. **(15) (E)**

4. Design the system using Nyquist plot G(S) = K(1+.5S)(1+S)/(1+10S)(S−1). Determine the range of values of K for which the system is stable**.(15) (C)**

UNIT V

CONTROL SYSTEM ANALYSIS USING STATE VARIABLE METHODS

Part A:

1. **List any four advantages of state space analysis? (R)**

It can be applied to non-linear as well as time varying systems. Any type of input can be considered for designing the system. It can be conveniently applied to multiple input multipleoutput systems. The state variables selected need not necessarily be the physical quantities of thesystem.

2. **What are phase variables? (R)**

The phase variables are defined as the state variables which are obtained from one of the system variables and its derivatives.

3. **Define state variable. (R)**

The state of a dynamical system is a minimal set of variables (known as state variables) such that the knowledge of these variables at t-t0 together with the knowledge of the inputs for t > t0, completely determines the behavior of the system for t > t0.

4. **Write the general form of state variable matrix. (R)**

The most general state-space representation of a linear system with m inputs, p outputs andn state variables is written in the following form:

X(t)= AX + BU

Y(t) = CX + DU

Where = state vector of order n X 1.

U = input vector of order n X1.

A=System matrix of order n X n.

B = Input matrix of order n X m C =output matrix of order p X n

D = transmission matrix of order p X m.

5. What is the necessary condition to be satisfied for design using state feedback? (AZ)

The state feedback design requires arbitrary pole placements to achieve the desire performance. The necessary and sufficient condition to be satisfied for arbitrary pole placement is that the system is completely state controllable.

6. What is controllability? (R)

A system is said to be completely state controllable if it is possible to transfer the systemstate from any initial state X(t0) at any other desired state X(t), in specified finite time by a control vector U(t).

7. What is observability? (R)

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.

8. Write the properties of state transition matrix. (U)

The following are the properties of state transition matrix Φ (0) = eAx0 = I (unit matrix).

Φ (t) = eAt = (e-At)-1 = [Φ(-t)]-1.

Φ (t1+t2) = eA(t1+t2) = Φ(t1) Φ(t2) = Φ(t2) Φ(t1).

9. What is similarity transformation? (R)

The process of transforming a square matrix A to another similar matrix B by a transformation P-1AP = B is called similarity transformation. The matrix P is called transformation matrix.

10. What is meant by diagonalization? (R)

The process of converting the system matrix A into a diagonal matrix by a similaritytransformation using the modal matrix M is called diagonalization.

11. What is the need for controllability test? (AZ)

The controllability test is necessary to find the usefulness of a state variable. If the state variables are controllable then by controlling (i.e. varying) the state variables the desired outputs ofthe system are achieved.

12. What is the need for observability test? (AZ)

- The observability test is necessary to find whether the state variables are measurable or not.

- If the state variables are measurable then the state of the system can be determined by practical measurements of the state variables.

13. State the condition for observability by Gilbert's method. (R)

Consider the transformed canonical or Jordan canonical form of the state model shown below which is obtained by using the transformation,

$$X = MZ = \Lambda Z + U$$

$$Y = Z + DU \text{ (Or) } = JZ + U$$

$$Y = Z + DU \text{ where } = CM \text{ and } M = \text{modal matrix.}$$

The necessary and sufficient condition for complete observability is that none of the columns of the matrix be zero. If any of the column is of have all zeros then the corresponding state variable is not observable.

14. State the duality between controllability and observability. (R)

- The concept of controllability and observability are dual concepts and it is proposed by kalman as principle of duality.
- The principle of duality states that a system is completely statecontrollable if and only if its dual system is completely state controllable if and only if its dualsystem is completely observable or vice versa.

15. What is the need for state observer? (AZ)

In certain systems the state variables may not be available for measurement and feedback. In such situations we need to estimate the immeasurable state variables from the knowledge of input and output. Hence a state observer is employed which estimates the state variables from the input and output of the system. The estimated state variable can be used for feedback to design the system by pole placement.

16. How will you find the transformation matrix, Po to transform the state model to observable phase variable form? (E)

- Compute the composite matrix for observability,Q0
- Determine the characteristic equation of the system $|\lambda I - A| = 0$.
- Using the coefficients a1,a2,….an-1 of characteristic equation form a matrix, W.
- Now the transformation matrix, P0 is given by P0=W Q0T.

17. What is the pole placement by state feedback? (R)

The pole placement by state feedback is a control system design technique, in which the state variables are used for feedback to achieve the desired closed loop poles.

18. How control system design is carried in state space? (AZ)

- In state space design of control system, any inner parameter or variable of a system are used for feedback to achieve the desired performance of the system.
- The performance of thesystem is related to the location of closed loop poles.
- Hence in state space design the closed loop poles are placed at the desired location by means of state feedback through an appropriate state feedback gain matrix, K.

Part B:

1. Explain the stability analysis of digital control systems. **(13) (U)**
2. Mention in detail a state space representation of a continuous time systems and discrete time systems.**(13) (R)**
3. Determine the z-domain transfer function for the following s- domain transfer function for the following s-domain transfer functions. **(13) (E)**

   i)$H(s) = a/(s+a)^2$ **(4)**

   ii)$H(s) = s / s2 + w 2$ **(5)**

   iii)$H(s) = a / s^2 - a^2$ **(4)**
4. Apply the necessary equations to obtain the Z-transform of following discrete time sequences. **(13) (A)**

   (i) ak (k+1)(k+2)/ 2! **(5)**

   (ii) ak (k+1)(k+2)(k+3)/ 3! **(4)**

   (iii) ak/ k! **(4)**

5. A system is represented by State equation $\dot{X}$ = AX+BU;

   Y=CX Where

   $$A=\begin{bmatrix} 0 & 1 & 0 \\ 0 & -1 & 1 \\ 0 & -1 & -10 \end{bmatrix},\ B=\begin{bmatrix} 0 \\ 0 \\ 10 \end{bmatrix} \text{ and } C=[1\ 0\ 0].$$

   Determine the Transfer function of the System. **(13) (E)**
6. A System is characterized by the Transfer function Y(S)/ U(S) $= 3/(s^3 + 5s^2 + 11 s + 6)$.

Express whether or not the system is completely controllable and observable and Identify the first state as output . **(13) (AZ)**

7. Test the controllability and observability of the system by any one method whose state space representation is given as **(13) (E)**

x1 0 0 1 x1 0
[x2] = [−2−3 0] [x2] + [2] u
x3 0 2 −3 x3 0

x1
Y = [1 0 0] [x2]
x3

8. (i) Develop the Transfer function of the matrix from the data given below **(C)**

A= [−3 1] B= [1 C=[1 1] D=[0] . **(7)**
0 −1 1]

(ii) The Transfer function of a Control System is given by **(C)**

Y(S) / U(S) = (s+2) /(s^3 +9s^2 +26 s+24) and plan the controllability of the system**.(6)**

9. Mention the Transfer Function of the system. The State Space representation of a System is given below. **(13) (A)**

$\dot{x}1$ −2 1 0 $x1$ 0
($\dot{x}2$) =(0 −3 1) ($x2$) + (0) u
$\dot{x}3$ −3 −4 −5 $x3$ 1

$x1$
Y= (0 0 1) ($x2$)
$x3$

10. Research the stability of the digital control system represented by the following characteristic equation $^3 - 0.2z^2 - 0.25z + 0.05 = 0$. **(13) (AZ)**

11. Examine how controllability and observability for a system can be tested, with an example. **(13) (E)**

12. A discrete time system has the transfer function (z)/ U(z) = $4z^3 - 12z^2$ + 13z – 7/(z − 1)2($z - 2$) . Determine the state model of the system in Canonical form. **(13) (A)**

13. A discrete system is defined by the difference equation $y(k + 2) + 5y(k + 1) + 6y(k) = u(k)$ y(0)=y(1)=0;T=1 sec Define the state model in canonical form. Draw the block diagram. **(13) (C)**

14. (i) Obtain the state model of the system described by the following transfer $Y(s) / U(s) = 10/ s^3 + 4s^2 + 2s + 1$. **(7) (E)**

(ii) Express the state transition matrix for the state model whose system matrix A is given by **(6) (U)**

$$A = \begin{matrix} 4 & 1 & -2 \\ 1 & 0 & 2 \\ 1 & -1 & 3 \end{matrix}$$

Part C:

1. Construct a state model for a system characterized by the differential equation d3y/dt3 + $6\, d^2y/dt^2 + 11\, dy/dt + 6y + u = 0$. **(15)**
2. A feedback system has a closed loop transfer function $Y(s)/U(s) = 10(s + 4)/(s + 1)(s + 3)$ .Construct a state model for this system. **(15)**
3. Estimate the solution of the difference equation
   $c(k + 2) + 3c(k + 1) + 2c(k) = u(k)$
   Given that c(0)=1 ; c(1)=-3 ; c(k)=0 for k<0. (15)
4. Write the Z-domain transfer function of following s- domain transfer function.
   i) $k/ s(s+4)$ **(5)**
   ii) $(a-b)/ (s+a)(s+b)$ **(5)**
   iii) $b/ s(s+b)$ **(5)**

Faculty Incharge
( )

Head of the Department
( )

HoD Remarks: