MARIA COLLEGE OF ENGINEERING AND TECHNOLOGY, ATTOOR

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

EC46 CONTROL SYSTEMS

2 MARKS QUESTIONS & ANSWERS

UNIT-I

CONTROL SYSTEM MODELING

1. What is control system?

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. Define open loop control system.

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

3. Define closed loop control system.

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.

4. What are the components of feedback control system?

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

5. Distinguish between open loop and closed loop system

S.No	OPEN LOOP	CLOSED LOOP
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.	May oscillate and become unstable	They are generally stable Great efforts are needed to design a stable system

6. Define transfer function.

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.

7. What are the basic elements used for modeling mechanical translational system.

- Mass M, Kg,
- Stiffness of spring K, N/m
- and Viscous friction coefficient dashpot B, N-sec/m

8. What are the basic elements used for modeling mechanical rotational system?

- Moment of inertia J, Kg-m^2/rad
- dashpot with rotational frictional coefficient B, N-m/(rad/sec)
- And torsional spring with stiffness K ,N-m /rad.

9. Name two types of electrical analogous for mechanical system.

The two types of analogies for the mechanical system are

- Force voltage and
- Force current analogy

10. What is block diagram?

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.

11. What are the basic components of Block diagram?

The basic elements of block diagram are blocks, branch point and summing point.

12. What is the basis for framing the rules of block diagram reduction technique?

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

13. What is a signal flow graph?

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

14. 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.

15. What is sink and source?

Source is the input node in the signal flow graph and it has only outgoing branches. Sink is a output node in the signal flow graph and it has only incoming branches.

16. Define non touching loop.

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

17. Write the analogous electrical elements in force voltage analogy for the elements of mechanical translational system.

Force, f à Voltage, e

Velocity, V à current, i

Displacement, x à charge, q

Frictional coefficient, B à Resistance, R

Mass, M à inductance, L

Stiffness, K à Inverse of capacitance 1/C

Newton's second law à Kirchhoff's voltage law.

18. Write the analogous electrical elements in force current analogy for the elements of mechanical translational system.

Force, f à current, i

Velocity, V à Voltage, e

Displacement, x à flux, Φ

Frictional coefficient, B à Conductance, G =1/ R

Mass, M à capacitance C

Stiffness, K à Inverse of inductance, 1/L

19. Write the analogous electrical elements in torque voltage analogy for the elements of mechanical rotational system.

Torque, T à Voltage, e

Angular Velocity, ω à current, i

Angular Displacement, θ à charge, q

Frictional coefficient, B à Resistance, R

Moment of Inertia, J à inductance, L

Stiffness of the spring, K à Inverse of capacitance 1/C

20. Write the analogous electrical elements in torque current analogy for the elements of mechanical rotational system.

Torque, T à current, i

Angular Velocity, ω à Voltage, e

Angular Displacement, θ à flux, Φ

Frictional coefficient, B à Conductance, G =1/ R

Moment of Inertia,J à capacitance C

Stiffness of the spring, K à Inverse of inductance, 1/L

16 marks

1. Explain the Rules of Block diagram reduction technique in detail.
2. Explain control system modeling using analogous circuits
3. Derive the transfer function of armature controlled D motor
4. Explain the onepts of signal flow graph
5. Explain mechanical and rotational systems

UNIT-2

TIME RESPONSE ANALYSIS

1. 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.

2. What is step signal?

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

3. 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.

4. 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.

5. What is transient response?

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

6. What is steady state response?

The steady state response is the response of the system when it approaches infinity.

7. Define Damping ratio.

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

8. List the time domain specifications.

The time domain specifications are

i. Delay time

ii. Rise time

iii. Peak time

iv. Peak overshoot

9. What is damped frequency of oscillation?

In under damped system the response is damped oscillatory. The frequency of damped oscillation is given by $\omega_d = \omega_n \sqrt{(1- \zeta^2)}$

10. What will be the nature of response of second order system with different types of damping?

For undamped system the response is oscillatory.

For under damped system the response is damped oscillatory.

For critically damped system the response is exponentially rising.

For over damped system the response is exponentially rising but the rise time will be very large.

11. Define Delay time.

The time taken for response to reach 50% of final value for the very first time is delay time.

12. Define Rise time.

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

13. Define peak time

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

14. Define peak overshoot.

Peak overshoot is defined as the ratio of maximum peak value measured from the Maximum value to final value

15. Define Settling time.

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

16. What is the need for a controller?

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

17. What are the different types of controllers?

The different types of the controller are

- Proportional controller
- PI controller
- PD controller
- PID controller

18. What is proportional controller?

It is device that produces a control signal which is proportional to the input error signal.

19. What is PI controller?

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.

20. What is PD controller?

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

21. What is the significance of integral controller and derivative controller in a PID controller?

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

22. Define Steady state error.

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

23. What is the drawback of static coefficients?

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

24. What are the three constants associated with a steady state error?

The three steady state errors constant are

- Positional error constant K_p
- Velocity error constant K_v

- Acceleration error constant K_a

25. What are the main advantages of generalized error co-efficients?

i) Steady state is function of time.

ii) Steady state can be determined from any type of input.

26. What are the effects of adding a zero to a system?

Adding a zero to a system results in pronounced early peak to system response thereby the peak overshoot increases appreciably.

27. Why derivative controller is not used in control system?

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

28. What is the effect of PI controller on the system performance?

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

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

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

30. What is the disadvantage in proportional controller?

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

16 marks

1. (a)Derive the expressions and draw the response of first order system for unit step input.

(b) Draw the response of second order system for critically damped case and when input is unit step.

2. Derive the expressions for Rise time, Peak time, and Peak overshoot.

4. Measurements conducted on a Servomechanism show the system response to be c(t)=1+0.2 e^{60t}-1.2 e^{-10t}, when subjected to a unit step. Obtain an expression for closed loop transfer function.

5. A positional control system with velocity feedback is shown in fig. What is the response c(t) to the unit step input. Given that K =0.5.and also calculate rise time, peak time, Maximum overshoot and settling time.

6. A unity feedback control system has an open loop transfer function G(S) = 10/S(S+2). Find the rise time, percentage over shoot, peak time and settling time.

7. Explain in detail about the Proportional, Integral and derivative controller.

UNIT.3

FREQUENCY RESPONSE ANALYSIS

2 MARKS

1. What is frequency response?

A frequency response is the steady state response of a system when the input to the system is a sinusoidal signal.

2. List out the different frequency domain specifications?

The frequency domain specifications are

- Resonant peak.
- Resonant frequency.
- Bandwidth
- Cut-off rate
- Gain margin
- Phase margin

3. Define –resonant Peak

The maximum value of the magnitude of closed loop transfer function is called resonant peak.

4. What is bandwidth?

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.

5. 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.

6. Define –Gain Margin?

The gain margin, k_g is defined as the reciprocal of the magnitude of the open loop transfer function at phase cross over frequency. .

7. Define Phase cross over?

The frequency at which, the phase of open loop transfer functions is 180° is called phase cross over frequency ω_{pc}.

8. What is phase margin?

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

9. Define Gain cross over?

The gain cross over frequency ω_{gc} is the frequency at which the magnitude of the open loop transfer function is unity..

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

11. What are the main advantages of Bode plot?

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 is available. angle curve of $1+ j\omega$

12. Define Corner frequency?

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

13. Define Phase lag and phase lead?

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

14. What are M circles?

The magnitude M of closed loop transfer function with unity feedback will be in the form of circle in complex plane for each constant value of M. The family of these circles are called M circles.

15. What is Nichols chart?

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

16. What are two contours of Nichols chart?

Nichols chart of M and N contours, superimposed on ordinary graph. The M contours are the magnitude of closed loop system in decibels and the N contours are the phase angle locus of closed loop system.

17. What is non-minimum phase transfer function?

A transfer function which has one or more zeros in the right half S-plane is known as non-minimal phase transfer function.

18. What are the advantages of Nichols chart?

The advantages are:

i) It is used to find the closed loop frequency response from open loop frequency response.

ii) Frequency domain specifications can be determined from Nichols chart.

iii) The gain of the system can be adjusted to satisfy the given specification.

19. What are N circles?

If the phase of closed loop transfer function with unity feedback is α, then $N=\tan \alpha$. For each constant value of N, a circle can be drawn in the complex plane. The family of these circles are called N circles.

20. What are the two types of compensation?

The two types of compensation are

i. Cascade or series compensation.

ii. Feedback compensation or parallel compensation.

21. What are the three types of compensators?

The three types of compensators are

i. Lag compensator.

ii. Lead compensator.

iii. Lag-Lead compensator.

22. What are the uses of lead compensator?

The uses of lead compensator are

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

23. What is the use of lag compensator?

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

24. When lag-lead compensator is is required?

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

25. What is a compensator?

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

26. When lag/lead/lag-lead compensation is employed?

Lag compensation is employed for a stable system for improvement in steady state performance. Lead compensation is employed for stable/unstable system for improvement in transient state performance.

Lag-Lead compensation is employed for stable/unstable system for improvement in both steady state and transient state performance

27. What are the effects of adding a zero to a system?

Adding a zero to a system results in pronounced early peak to system response thereby the peak overshoot increases appreciably.

16 marks

1. Plot the Bode diagram for the following transfer function and obtain the gain and phase cross over frequencies.

$G(S) = 10/ S(1+0.4S) (1+0.1S)$

2. Sketch the polar plot for the following transfer function .and find Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin.

$G(S) = 10(S+2)(S+4)/ S (S^2 -3S+10)$

3. Construct the polar plot for the function $GH(S) =2(S+1)/ S^2$. Find Gain cross over frequency ,Phase cross over frequency, Gain margin and Phase margin.

4. A unity feedback system has open loop transfer function $G(S) = 20/ S (S+2)(S+5)$.Using Nichol's chart determine the closed loop frequency response and estimate all the frequency domain specifications.

5. Sketch the Bode plot and hence find Gain cross over frequency, Phase cross over frequency, Gain margin and Phase margin.

$G(S) = 10(1+0.1S)/ S(1+0.01S) (1+S)$.

5. A unity feedback system has an open loop transfer function

$G(S)= K/ S(S+1) (0.2S+1)$.

Design a suitable phase lag compensators to achieve following specifications $K_v= 8$ and Phase margin 40 deg with usual notation.

UNIT-4

STABILITY ANALYSIS

1. Define stability.

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

2. What is nyquist contour

The contour that encloses entire right half of S plane is called nyquist contour.

3. State Nyquist stability criterion.

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

4. Define Relative stability

Relative stability is the degree of closeness of the system; it is an indication of strength or degree of stability.

5. What will be the nature of impulse response when the roots of characteristic equation are lying on imaginary axis?

If the root of characteristic equation lies on imaginary axis the nature of impulse response is oscillatory.

6. What is the relationship between Stability and coefficient of characteristic polynomial?

If the coefficient of characteristic polynomial are negative or zero, then some of the roots lie on the negative half of the S-plane. Hence the system is unstable. If the coefficients of the characteristic polynomial 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.

7. What is Routh stability criterion?

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.

8. What is limitedly stable system?

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.

9. In routh array what conclusion you can make when there is a row of all zeros?

All zero rows in the routh array indicate the existence of an even polynomial as a factor of the given characteristic equation. The even polynomial may have roots on imaginary axis.

10. What is a principle of argument?

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

11. What are the two segments of Nyquist contour?

i. An finite line segment C1 along the imaginary axis.

ii. An arc C2 of infinite radius.

12. What are root loci?

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

13. What is a dominant pole?

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

14. What are the main significances of root locus?

i. The root locus technique is used for stability analysis.

ii. Using root locus technique the range of values of K, for as stable system can be determined

15. What are break away and break in points?

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 a 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.

16. What are asymptotes? How will you find angle of asymptotes?

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

Angles of asymptotes = $\pm 180°(2q + 1)/(n-m)$ $q= 0,1,2, \ldots\ldots(n-m)$

n-number of poles.

m-number of zeros.

17. What is centroid?

The meeting point of the asymptotes with the real axis is called centroid. The centroid is given by

Centroid = (sum of poles – sum of zeros) / (n-m)

n-number of poles.

m-number of zeros.

18. What is magnitude criterion?

The magnitude criterion states that $s=s_a$ will be a point on root locus if for that value of S, magnitude of G(S)H(S) is equal to 1.

$|G(S)H(S)|$ = K(product of length of vectors from open loop zeros to the point $s=s_a$)/ (product of length of vectors from open loop poles to the point $s=s_a$) = 1.

19. What is angle criterion?

The angle criterion states that $s=s_a$ will be the point on the root locus if for that value of S the argument or phase of G(S)H(S) is equal to an odd multiple of 180°.

(Sum of the angles of vectors from zeros to the point $s=s_a$)- (Sum of the angles of vectors from poles to the point $s=s_a$) = $\pm 180°(2q + 1)$

20. How will you find the root locus on real axis?

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 on the root locus. If it is even then the test point does not lie on the root locus

16 marks

1. Using Routh criterion determine the stability of the system whose characteristics equation is

$S^4+8S^3+18S^2+16S+5 =0.$

2. $F(S) =S^6 +S^5-2S^4-3S^3-7S^2-4S-4 =0$.Find the number of roots falling in the RHS plane and LHS plane.

3. Draw 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 closed loop system is stable.

4. Construct Nyquist plot for a feedback control system whose open loop transfer function is given by $G(S)H(S) =5/ S(1-S)$.comment on the stability of open loop and closed loop transfer function.

5. Sketch the Nyquist plot for a system with the open loop transfer function

$G(S) H(S) =K (1+0.5S) (1+S) / (1+10S) (S-1).$

Determine the range of values of K for which the system is stable.

UNIT-5

STATE VARIABLE ANALYSIS & DIGITAL CONTROL SYSTEMS

1. Define state variable.

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-t_0 together with the knowledge of the inputs for $t > t_0$, completely determines the behavior of the system for $t > t_0$

2. What are the methods available for the stability analysis of sampled data control system?

The following three methods are available for the stability analysis of sampled data control system

1. Juri's stability test.

2. Bilinear transformation.

3. Root locus technique.

3. What is the necessary condition to be satisfied for design using state feedback?

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.

4. What is controllability?

A system is said to be completely state controllable if it is possible to transfer the system state from any initial state $X(t_0)$ at any other desired state X(t), in specified finite time by a control vector U(t).

5. What is observability?

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.

6 Define sampling theorem.

Sampling theorem states that a band limited continuous time signal with highest frequency f_m, hertz can be uniquely recovered from its samples provided that the sampling rate F_s is greater than or equal to $2f_m$ samples per second.

7 What is sampled data control system?

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.

8. What is Nyquist rate?

The Sampling frequency equal to twice the highest frequency of the signal is called as Nyquist rate.

$f_s=2f_m$

9. What is similarity transformation?

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

10. What is meant by diagonalization?

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

11. What is modal matrix?

The modal matrix is a matrix used to diagonalize the system matrix. It is also called diagonalization matrix.

If A = system matrix.

M = Modal matrix

And M^{-1}=inverse of modal matrix.

Then $M^{-1}AM$ will be a diagonalized system matrix.

12. How the modal matrix is determined?

The modal matrix M can be formed from eigenvectors. Let $m_1, m_2, m_3 \ldots. m_n$ be the eigenvectors of the n^{th} order system. Now the modal matrix M is obtained by arranging all the eigenvectors column wise as shown below.

Modal matrix , $M = [m_1, m_2, m_3 \ldots. m_n]$.

13. 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 (i.e. varying) the state variables the desired outputs of the system are achieved.

14. What is the need for observability test?

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.

15. State the duality between controllability and observability.

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 state controllable if and only if its dual system is completely state controllable if and only if its dual system is completely observable or viceversa.

16. What is the need for state observer?

In certain systems the state variables may not be available for measurement and feedback. In such situations we need to estimate the unmeasurable 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.

17. How will you find the transformation matrix, P_o to transform the state model to observable phase variable form?

- Compute the composite matrix for observability,Q_0
- Determine the characteristic equation of the system $|\lambda I - A| = 0$.
- Using the coefficients $a_1, a_2, \ldots a_{n-1}$ of characteristic equation form a matrix, W.
- Now the transformation matrix, P_0 is given by $P_0 = W Q_0^T$.

18. What is the pole placement by state feedback?

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.

19. How control system design is carried in state space?

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 the system 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.

16 marks

1. Derive the expression for the sampling theorem
2. Explain the concepts of controllability and observability

3. Briefly explain I companion method and j ordan anonical form
4. Explain the methods of obtaining transfer function from state mode;ls
5. With neat diagram explain the sample and hold circuit