IC1251 -CONTROL SYSTEMS (2 MARKS)

UNIT-I

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. 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.

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.

The control system in which the output has an effect upon the input quantity so as to maintain the desired output value 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. Define transfer function.

The T.F 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, spring and dashpot

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

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

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

11. 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.

12. What is a signal flow graph?

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.

13. What is transmittance?

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

14. What is sink and source?

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

15. Define nontouching loop.

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

16. Write Masons Gain formula.

Masons Gain formula states that the overall gain of the systm is
T = 1/ __k Pk _k
k-o.of forward paqths in the signal flow graph.
Pk- Forward path gain of kth forward path

_ = 1-[sum of individual loop gains] +[sum of gain products of allpossible combinations of two non touching loops]-[sum of gain products of allpossible combinations of three non touching loops]+…
_k - _ for that part of the graph which is not touching kth forward path.

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

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

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

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

19. Write the force balance equation ofm ideal mass element .

$F = M\, d2x /dt2$

20. Write the force balance equation of ideal dashpot element .

$F = B\, dx /dt$

21. Write the force balance equation of ideal spring element .

$F = Kx$

22. Distinguish between open loop and closed loop system

Open loop Closed loop
1.Innaccurate
2.Simple and economical
3.The changes in output due to external disturbance are not corrected
4.They are generally stable
Accurate
Complex and costlier
The changes in output due to external disturbances are corrected automatically
Great efforts are needed to design a stable system

23. What is servomechanism?

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

24. Why is negative feedback invariably preferred in closed loop system?

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

UNIT-2

1. What is Proportional controller and what are its advantages?

The Proportional controller is a device that produces a control signal which is proportional to the input error signal.

The advantages in the proportional controller are improvement in steady-state tracking accuracy, disturbance signal rejection and the relative stability. It also makes a system less sensitive to parameter variations.

2. What is the drawback in P-controller?

The drawback in P-controller is that it develop a constant steady-state error.

3. What is integral control action?

In integral control action, the control signal is proportional to integral of error signal.

4. What is the advantage and disadvantage in integral controller?

The **advantage** in Integral controller is that it eliminates or reduces the steady-state error. The **disadvantage** is that it can make a system unstable.

5. What is *PI* controller?

The PI controller is a device which produces a control signal consisting of two terms-one proportional to error signal and the other proportional to the integral of error signal.

6. What is *PD* controller?

The PD controller is a device which produces a control signal consisting of two terms-one proportional to error signal and the other proportional to the derivative of error signal.

7. What is *PID* controller?

The PID controller is a device which produces a control signal consisting of three terms-one proportional to error signal, another one proportional to integral of error signal and the third one proportional to derivative of error signal.

8. What is time response?

The time response is the output of the closed loop system as a function of time. It is denoted by c(t). It is given by inverse Laplace of the product of input and transfer function of the system.

The closed loop transfer function, $\frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)}$

Response in s-domain, $C(s) = \frac{R(s)\,G(s)}{1+G(s)H(s)}$

Response in time domain, $c(t) = L^{-1}[C(s)] = L^{-1}\frac{R(s)\,G(s)}{1+G(s)H(s)}$

9. What is transient and steady state response?

The transient response is the response of the system when the input changes from one state to another. The response of the system as $t \rightarrow \infty$ is called steady-state response.

10. What is the importance of test signals?

The test signals can be easily generated in test laboratories and the charecteristics of test signals resembles, the characteristics of actual input signals. The test signals are used to predetermine the performance of the system. If the response of a system is satisfactory for a test signal, then the system will be suitable for practical applications.

11. Name the test signals used in control system:

The commonly used test input signals in control system are impluse, step, ramp, acceleration and sinusoidal signals.

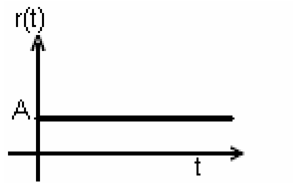
12. Define **Step signal:**

The step signal is a signal whose value changes from 0 to A and remains constant at A for $t > 0$. The mathematical representation of step signal is

$$r(t) = A\,u(t)$$

Where, $u(t) = 1, t > 0$

$u(t) = 0, t<0$

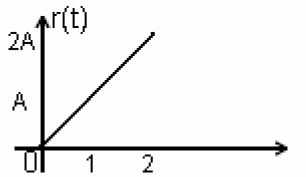


13. Define **Ramp signal:**

A ramp signal is a signal whose value increases linearly with time from an initial value of zero at $t = 0$. It is mathematically represented as

$$r(t) = A\,t,\ t > 0$$

$$= 0, \quad t < 0$$

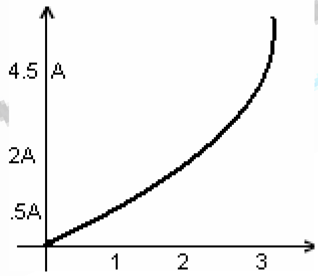


14. Define **parabolic signal:**

It is a signal in which the instantaneous value varies as square of the time from an initial value of zero at $t = 0$. It is mathematically represented as

$$r(t) = \frac{A\,t^2}{2},\ t>0$$

$$= 0, \quad t<0$$



15. What is an impulse signal?

A signal which is available for very short duration is called impulse signal. Ideal impluse signal is a unit impulse signal which is defined as a signal having zero values at all time except at $t = 0$. At $t = 0$ the magnitude becomes infinite. It is ted by $\delta(t)$ and mathematically expressed as

$\delta(t) = 0$ for $t \neq 0$ and $$\lim_{t1 \to 0} \int_{-t1}^{+t1} \delta(t)\, dt = 1$$

16. What is the order of a system?

The order of the system is given by the order of the differential equation governing the system. It is also given by the maximum power of s in the denominator polynomial of transfer function. The maximum power of s also gives the number of poles of the system and so the order of the system is also given by number of poles of the transfer function.

17. Define **Damping ratio:**

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

18. Give the expression for damping ratio of mechanical and electrical system:

The damping ratio of second order mechanical translational system, $\tau = B / 2\sqrt{MK}$

The damping ratio of second order mechanical rotational system, $\tau = B / 2\sqrt{JK}$

The damping ratio of second order electrical system, $\tau = R / 2 \sqrt{(L/C)}$

19. How the system is classified depending on the value of damping?

Depending on the value of damping, the system can be classified into the following four cases

Case 1 : Undamped system, $\tau = 0$

Case 2 : Underdamped system, $0 < \tau < 1$

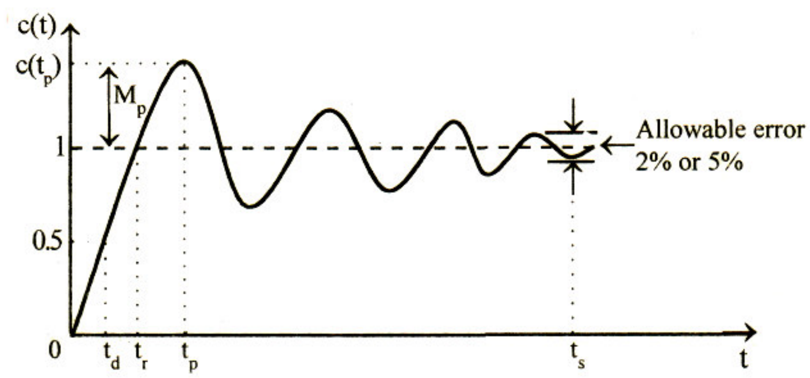
Case 3 : Critically damped system, $\tau = 1$

Case 4 : Over damped system, $\tau > 1$.

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

- For undamped system the response is oscillatory.
- For underdamped system the response is damped oscillatory.
- For critically damped system the response is exponentially rising.
- For overdamped system the response is exponentially rising but the rise time will be very large.

21. Sketch the response of a second order underdamped system:



22. What is damped frequency of oscillation?

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

23. List the time domain specifications:

The time domain specifications are :

(i) Delay time

(ii) Rise time

(iii) Peak time

(iv) Maximum overshoot

(v) Settling time.

24. Define **Dlay time:**

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

25. Define **rise time:**

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

- For underdamped system, the rise time is calculated from 0 to 100%.
- For overdamped system it is the time taken by the response to raise from 10% to 90%.
- For critically damped system, it is the time taken for response to raise from 5% to 95%.

26. Define **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 peak overshoot, M_p .

27. Define **Peak overshoot:**

It is defined as the ratio of the maximum peak value measured from final value to final value. Let final value = $c(\infty)$, Maximum Value = $c(t_p)$

Peak Overshoot, $M_p = [\ c(t_p) - c(\infty)\ ] / c(\infty)$

28. Define **settling time:**

It is defined as the time taken by the response to reach and stay within a specified error and the error is usually specified as % of final value. The usual tolerable error is 2% or 5% of the final value.

29. What is type number of a system? What is its significance?

The type number is given by number of poles of loop transfer function at the origin. The type number of the system decides the steady state error.

30. Distinguish between type and order of a system:

(i) Type number is specified for loop transfer function but order can be specified for any transfer function. (open loop or closed loop transfer function).

(ii) The type number is given by number of poles of loop transfer function lying at origin of s-plane but the order is given by the number of poles of transfer function.

31. What is steady state error?

The steady state error is the value of error signal e(t), when t tends to infinity . The steady state error is a measure of system accuracy. These errors arise from the nature of inputs, type of system and from non-linearity of system components.

32. Define acceleration error constant:

The acceleration error constant $K_a = \lim_{s \to 0} S^2\, G(s)\, H(s)$.

The steady state error in type-2 system for unit parabolic input is given by $1/K_a$.

33. What are generalized error coefficients?

They are the coefficients of generalized error series.The generalized error series is given by

$e(t) = C_0 r(t) + C_1 \acute{r}(t) + (C_2/2!)\ r''(t) + (C_3/3!)\ r'''(t) + \dots\dots\dots\dots + (C_n/n!)\ r^{n'}(t)$

The coefficients $C_0, C_1, C_{2}, \ldots, C_n$ are called generalized error coefficients or dynamic error coefficients.

The n^{th} coefficient, $C_n = \lim_{s \to 0} d^n F(s)$,

Where $F(s) = \frac{1}{1 + G(s)H(s)}$

34. Give the relation between generalized and static error coefficients:

The following expression shows the relation between generalized and static error coefficient

$\mathbf{C_0 = 1/(1 + K_p)}$ $\mathbf{C_1 = 1/(K_v)}$ $\mathbf{C_2 = 1/(K_a)}$

35. Mention two advantages of generalized error constants over static error constants:

- Generalized error series gives error signal as a function of time.
- Using generalized error constants the steady state error can be detena for any type of input but static error constants are used to determine *m* state error when the input is anyone of the standard input.

Unit III

1. What is frequency response ?

The frequency response is a steady-state output of the system, when the input is a sinusoidal signal.

2. What are advantages of frequency response analysis ?

1. The absolute and relative stability of the closed loop system can be estimated from the knowledge of the open loop frequency response.
2. The practical testing of system can be easily carried with available sinusoidal signal generators and precise measurement equipments.
3. The transfer function of complicated functions can be determined experimentally by frequency response tests.
4. The design and parameter adjustment can be carried more easily.
5. The corrective measure for noise disturbance and parameter variation can be easily carried.
6. It can be extended to certain non-linear systems.

7. What are frequency domain specifications?

Fhe frequency domain specifications indicates the performance of the system in requency domain, and they are

1. Resonant peak
2. Resonant frequency
3. Bandwidth
4. Cut-off rate
5. Gain margin
6. Phase margin.

8. Define **Resonant Peak ?**

The maximum value of the magnitude of closed loop transfer function is called Resonant Peak.

9. What is **Resonant frequency ?**

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

10. Define **Bandwidth ?**

The Bandwidth is the range of frequencies for which the system gain is more lan -3db.

11. What is **cut-off rate ?**

The slope of the log-magnitude curve near the cut-off frequency is called cut-Off rate.

12. Define **gain margin ?**

The gain margin, Kg is defined as the reciprocal of the magnitude of open loop transfer function, at phase cross-over frequency, ω_{pc}.

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

When expressed in decibels, it is given by, the negative of db magnitude of G(jco) at phase cross-over frequency.

$$\text{Gain margin in db} = 20 \log \frac{1}{|G(j\omega)|_{\omega=\omega_{pc}}} = -20 \log |G(j\omega)|_{\omega=\omega_{pc}}$$

13. Define **phase margin?**

The phase margin, γ is that amount of additional phase lag at the gain cross over frequency, ω_{gc} required to bring the system to the verge of instability. It is given by, $180° + \phi_{gc}$, where ϕ_{gc} is the phase of $G(j\omega)$ at the gain cross over frequency.

$$\text{Phase margin, } \gamma = 180° + \phi_{gc}$$

$$\text{Where, } \phi_{gc} = \text{Arg}\,[G(j\omega)]_{\omega=\omega_{pc}}$$

14. What is **phase** and **Gain cross-over frequency ?**

The gain cross-over frequency is the frequency at which the magnitude of the open loop transfer function is unity.
The phase cross-over frequency is the frequency at which the phase of the open loop transfer function is 180°.

15. Write the expression for resonant peak and resonant frequency,

$$\text{Resonant frequency, } M_r = \frac{1}{2\tau\sqrt{(1-\tau)}}$$

$$\text{Resonant Peak, } \omega_r = \omega_n \sqrt{(1 - 2\tau^2)}$$

16. Write a short note on the correlation between the time and frequency response ?

There exist a correlation between time and frequency response of first or second order systems. The frequency domain specification can be expressed in terms of the time domain parameters τ, and ω . For a peak overshoot in time domain there is a corresponding resonant peak in frequency domain.

For higher order systems there is no explicit correlation between time and frequency response. But if there is a pair of dominant complex conjugate poles, then the system can be approximated to second order system and the correlation between time and frequency response can be estimated.

17. What is **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.

The magnitude plot is a graph between magnitude of a system transfer function in db and the frequency ω. The phase plot is a graph between the phase or argument of a system transfer function in degrees and the frequency ω. Usually, both the plots are plotted on a common x-axis in which the frequencies are expressed in logarithmic scale.

18. What is **approximate bode plot ?**

In approximate bode plot, the magnitude plot of first and second order factors are approximated by two straight lines, which are asymptotes to exact plot. One straight line is at 0db, for the frequency range 0 to ω_c and the other straight line is drawn with a slope of $\pm$ 20n db/dec for the frequency range ω_c to ∞. Here ω_c is the corner frequency.

19. Define **corner frequency ?**

The magnitude plot can be approximated by asymptotic straight lines. The frequencies corresponding to the meeting point of asymptotes are called corner frequency. The slope of the magnitude plot changes at every corner frequencies.

20. What are the advantages of Bode Plot ?

1. The magnitudes are expressed in db and so a simple procedure is to add magnitude of each term one by one.
2. The approximate bode plot can be quickly sketched, and the c: can be made at corner frequencies to get the exact plot.
3. The frequency domain specifications can be easily determined.
4. The bode plot can be used to analyse both open loop and ck system.

21. What is the value of error in the approximate magnitude plot of a ft factor at the corner frequency ?

The error in the approximate magnitude plot of a first order factor at t frequency is ± 3mdb, where m is multiplicity factor. Positive error for r factor and negative error for denominator factor.

22. What is the value of error in the approximate magnitude plot of a i factor with τ=l at the corner frequency ?

The error is ± 6db, for the quadratic factor with τ=l. Positive error for i factor and negative error for denominator factor.

23. What is a **Nichols plot?**

The Nichols plot is a frequency response plot of the open loop transfer function of a system. It is a graph between magnitude of $G(j\omega)$ in db and the phase of $G(j\omega)$ in degree, plotted on a ordinary graph sheet.

24. What are **M and N 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.

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

25. How closed loop frequency response is determined from open loop frequency response using M and N circles?

The $G(j\omega)$ locus or the polar plot of open loop system is sketched on the standard M and N circles chart. The meeting point of M circle with $G(j\omega)$ locus gives the magnitude of closed loop system, (the frequency being same as that of open loop system). The meeting point of $G(j\omega)$ locus with N-circle gives the value of phase of closed loop system, (the frequency being same as that of open loop system).

26. What is **Nichols chart?**

The Nichols chart consists of M and N contours superimposed on ordinary graph. Along each M contour the magnitude of closed loop system, M will be a constant. Along each N contour, the phase α of closed loop system will be constant. The ordinary graph consists of magnitude in db, marked on the y-axis and the phase in degrees marked on x-axis. The Nichols chart is used to find the closed loop frequency response from the open loop frequency response.

27. How the closed loop frequency response is determined from the open loop frequency response using Nichols chart?

The G(jω) locus or the Nichols plot is sketched on the standard Nichols chart. The meeting point of M contour with G(jω) locus gives the magnitude of closed loop system and the meeting point with N circle gives the argument/phase of the closed loop system.

28. What are the *advantages of Nichols chart*?

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

29. What is **polar plot ?**

The polar plot of a sinusoidal transfer function G(jω) is a plot of the magnitude of G(jω) versus the phase angle/argument of G(jω) on polar or rectangular coordinates as ω is varied from zero to infinity.

30. What is **minimum phase system ?**

The minimum phase systems are systems with minimum phase transfer functions. In minimum phase transfer functions, all poles and zeros will lie on the left half ofs-plane.

31. What is **All-Pass systems ?**

The all pass systems are systems with all pass transfer functions. In all pass transfer functions, 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 s-plane, there is a zero in the mirror image position with respect to imaginary axis).

UNIT-IV

1.) Define BIBO Stabiltiy ?
A linear relaxed system is said to have BIBO stability if every bounded input results in a bounded output.
2.) What is impulse response ?
The impulse response of a system is the inverse Laplace transform of the system transfer function.
3.) What is characteristic equation ?
The denominator polynomial C(s)/R(s) is the characteristic equation of the system.
4.) How the roots of characteristic equation are related to stability ?
If the roots 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 roots has negative real parts then the impulse response is bounded.Hence the system will be stable.
5.) What is the necessary condition for stability?

The necessary condition for stability is that all the coefficients of characteristic polynomial are positive.
6.) What is the relation between stability and coefficient of characteristic polynomial?

If the coefficients of characteristic polynomial are negative or 0,then some of roots lies on half of s-plane.Hence the system is unstable.If the coefficients of characteristic polynomial are positive and if no coefficient is 0 the there is a possibility of the system to be stable provided all the roots lie on left half os s-plane.
7.) What will be the nature of impulse response when the roots of characteristic equation are lying on imaginary axis?

The nature of impulse is oscillatory.
8.) What will be the nature of impulse response if the roots of characteristic equation are lying on right half s-plane?

When roots are lying on real axis on the right half of s-plane.The response is exponentially increasing.When the roots are complex conjugate and lying on the right half of s-plane,the response is oscillatory with exponentially,increasing amplitude.
9.) What is principle of argument?

The principle of argument states that let F(s) be an analytic function and if an arbitary closed contour in the clockwise direction is chosen in the s-plane so that F(s) is analytic at every point on the contour.Then the corresponding F(s) plane contour mapped in the F(s) plane will encircle the origin N times in the anticlockwise 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.
10.) What is the necessary and sufficient condition for stability?

The necessary and sufficient condition is that all of the elements in the first column of the routh array should be positive.
11.) What is routh stability condition?

Routh condition states that the necessary and sufficient condition for stability is that all of the elements in the first column of routh array be positive. If this condition is not met,the system is unstable and the number of of sign changes in the elements of the first column of routh array corresponds to number of roots of characteristic equation in the right half of s-plane.
12.) What is auxiliary polynomial?

In the construction of routh array a row of all zero indicates the existence of an even polynomial as a factor of the given characteristic equation.In an even polynomial the exponents of s are even integers or 0 only.This even polynomial factor is called auxiliary polynomial.
13.) What is quadrantal symmetry?

The symmetry of roots with respect to both real and imaginary axis is called quadrantal symmetry**.**
14.) In routh array what conclusion can you make when there is a row of all zeros?

All zero row indicates that the existence of an even polynomial as a factor of given characteristic equation.
15.) What is limitedly stable system?

For a bounded input signal,if the output has constant amplitude oscillations the the system may be stable or unstable under some limited constraints.Such a system is called Limitedly stable system.
16.) What is Nyquist stability criterion?

If G(s) H(s) contour in the G(s) H(s) palne 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 s-planes poles of G(s) H(s).Then the closed loop system is stable.
17.) What is root locus?

The path taken by a root of characteristic equation when open loop gain K is varied from 0 to infinity is called root locus.
18.) What is magnitude direction?

The magnitude direction condition states that s=sa will be a point on root locus if for the value of s ,magnitude of G(s) H(s) if equal to 1.

19.) What is angle direction?

The angle direction states that s=sa will be point on the root locus if for that value os s the argument or phase of G(s) H(s) if equal to an odd multiple of 180.

20.) How will you find gain K at a point on root locus?

K=Product of length of vector from open loop poles to the point sa
Product of length of vector from open loop zeros to the point sa

21.) How will you find root locus on real axis?

Choose a 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 lies on the root locus.

22.) What are asymptotes?How do u find the angle of asymptotes?

Asymptotes are straight lines which are parallel to root locus going to infinity an meet the root locus at infinity.
Angle--+or - 180(2q+1)/n-m, q------0,1,2,----(n-m)

23.) What is centroid ,How it is calculated?

The meeting point of asymptotes with real axis is called centroid.
CENTROID=sum of poles-sum of zeros /n-m

24.) What is breakaway point and breakin point?

At breakaway point the root locus breaks from the real axis to enter into the complex plane.At breakin point the root locus enters the real axis from complex plane

25.) What is dominant pole?

The dominant point 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.

26.) How do you find the crossing point of root locus in imaginary axis?

By Routh Hurwitz method.

UNIT V

1. What are the time domain specifications needed to design a control system?

The time domain specifications needed to design a control system are:-

1. Rise time, t_r 2. Peak overshoot , M_p 3. Setting time, t_s
4.Damping ratioζ 5. Natural frequency of oscillation, ω_n

2. Write the necessary frequency domain specification for design of a control system.

The frequency domain specifications required to design a control system are

1. Phase margin 2. Gain margin 3. Resonant peak 4. Bandwidth

3. What is compensation?

The compensation is the design procedure in which the system behaviour is altered to meet the desired specifications by introducing additional device called compensator.

4. What is compensator? What are the different types of compensator?

The device inserted into the system for the purpose of satisfying the specifications is called compensator.
The different types of compensators are lag compensator, lead compensator and lag-lead compensator.

5. What are the two types of compensation schemes?

. The two types of compensation schemes employed in control system are Series compensation and feedback or paralled compensation.

6. What is series compensation?

The series compensation is a design procedure in which a compensator is introduced in series with plant to alter the system behaviour and to provide satisfactory performance (i.e., to meet the desired specifications).
$G_c(s)$ = Transfer function of series compensator
$G(s)$ = Open loop transfer function of the plant
$H(s)$ = Feedback path transfer function.

7. What is feedback compensation?

The feedback compensation is a design procedure in which a compensator is introduced in the feedback path so as to meet the desired specifications.
It is also called parallel compensation.
$G_c(s)$ = Transfer function of series compensator
$G_1(s)\, G_2(s)$ = Open loop transfer function of the plant
$H(s)$ = Feedback path transfer function.

8. What are the factors to be considered for choosing series or shunt/feedback compensation?

The choice between series, shunt or feedback compensation depends on the following:
Nature of signals in the systems.
Power levels at various points.
Components available.
Designer’s experience.
Economic considerations.

9. 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.

10. Why compensation is necessary in feedback control system?

In feedback control systems compensation is required in the following situations.

When the system is absolutely unstable, then compensation is required to stabilize the system and also to meet the desired performance.
When the system is stable, compensation is provided to obtain the desired performance.

11. Discuss the effect of adding a pole to open loop transfer function of a system.

The addition of a pole to open loop transfer function of a system will reduce the steady state error. The closer the pole to origin lesser will be the steady-state error. Thus the steady- state performance of the system is
improved. Also the addition of pole will increase the order of the

system, which in turn makes the system less stable than the original system.

12. Discuss the effect of adding a zero to open loop transfer function of a system.

The addition of a zero to open loop transfer function of a system will improve the transient response. The addition of zero 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 from the origin in the left half of s-plane then the effect of zero on the transient response will be negligible.

13. What are the advantages and disadvantages in frequency domain design.

The advantages of frequency domain design are the following:

The effect of disturbances, sensor noise and plant uncertainties are easy to visualize and asses in frequency domain. The experimental information can be used for design purposes.

The disadvantages of frequency response design is that it gives the information on closed loop system's transient response indirectly.

14. What is lag-compensation?

The lag compensation is a design procedure in which a lag compensator is introduced in the system so as to meet the desired specifications.

15. What is a lag compensator? Give an example.

A compensator having the characteristics of lag network is called lag compensator. If a sinusoidal signal is applied to a lag compensator, then in steady state the output will have a phase lag and lead with respect to input.

An electrical lag compensator can be realised by an R-C network. The R-C network shown in the figure is an example of electrical lag compensator

16. What are the characteristics of lag compensation? When lag compensation is employed?

The lag compensation improves the steady state performance, reduces the bandwidth and increases the rise time. The increase in rise time results in slower transient response. If the pole introduced by the compensator is not cancelled by the zero in the system, then lag compensator increases the order of the system by one.

When the given system is stable and does not satisfy the steady-state performance specifications then lag compensation can be employed so that the system is redesigned to satisfy the steady-state requirements.

17. Draw the bode plot of lag compensator.

Let, G_c (jω) = Sinusoidal transfer function of lag compensator. The appropriate magnitude plot and phase plot of G_c (jω) are shown in the figure.

18. What is lead compensation?

The lead compensation is a design procedure in which a lead compensator is introduced in the system so as to meet the desired specifications.

19. What is lead compensator? Give an example.

A compensator having the characteristic of a lead network is called a lead compensator. If a sinusoidal signal is applied to a lead compensator, then in steady state the output will have a phase lead with respect to input. An electrical lead compensator can be realised by a RC network. The R-C network shown in the figure is an example of electrical lead compensator.

20. Write the transfer function of lead compensator and draw its pole-zero plot.

Transfer function of lead compensator Gc (s) =
$$\frac{S+\frac{I}{T}}{S+\frac{I}{\alpha T}}$$

The lead compensator has a pole at s= -1/αT and a zero at s = - 1/T. Since α < 1 and T > 0, the zero of lead compensator is nearer to origin. The pole-zero plot of lead compensator is shown in the figure.

25. What are the characteristics of lead compensation? When lead compensation is employed?

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 the 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.

26. Draw the bode plot of lead compensator.

Let, Gc (jω) = Sinusoidal transfer function of lead compensator. The appropriate magnitude plot and phase plot of Gc (jω) are shown in the figure.

27. What is the relation between ϕ_m and α in a lead compensator?

In lead compensator the ϕ_m and α are related by the expression,

$$\phi_m = \tan^{-1}\left(\frac{1-\alpha}{2-\sqrt{\alpha}}\right) \text{or } \alpha = \frac{1-\sin\phi_m}{1+\sin\phi_m}$$

Since α < 1 from the above expression we can conclude that, smaller the value of α the larger will be the value of ϕ_m.

28. When the maximum phase lead occurs in lead compensator? Give the expressions for maximum lead angle and the corresponding frequency.

The maximum phase lead occurs at the geometric mean of two corner frequencies of the lead compensator.

Maximum phase lead angle,

$$\phi_m = \tan^{-1}\left(\frac{1-\alpha}{2\sqrt{\alpha}}\right)$$

Frequency corresponding to maximum phase lead angle

$$\omega_m = \sqrt{\omega_{c1}\omega_{c2}} = \sqrt{\frac{1}{T}*\frac{1}{\alpha T}} = \frac{1}{T\sqrt{\alpha}}$$

29. Write the two equations that relates α and ϕ_m of lead compensator

$$\phi_m = \tan^{-1}\left(\frac{1-\alpha}{2\sqrt{\alpha}}\right) \quad \& \quad \alpha = \frac{1-\sin\phi_m}{1+\sin\phi_m}$$

30. What is lag- lead compensation?

The lad-lead compensation is a design procedure in which a lag-lead compensator is introduced in the system so as to meet the desired specifications.

31. What is a lag-lead compensator? Give an example.

A compensator having the characteristics of lag-lead network is called lag-lead compensator. If a sinusoidal signal is applied to a lag-lead compensator then the output will have both phase lag and lead with respect to input, but in different frequency regions.

An electrical lag-lead compensator can be realised by an R-C network. The R-C network shown in the figure is an example of electrical lag-lead compensator.

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

Transfer function of lag-lead compensator Gc (s) =

$$\frac{S+\frac{I}{T_1}}{S+\frac{I}{\beta T_1}} * \frac{S+\frac{I}{T_2}}{S+\frac{I}{\alpha T_2}}$$

33. What are the characteristics of lag-lead compensation? When lag-lead compensation is employed?

The lag-lead compensation has the characteristics of both lag compensation and lead compensation. The compensation improves the steady state performance and decreases the bandwidth. The lead compensation increases the bandwidth and improves the speed of response. It also reduces the peak overshoot. If the poles introduced by the compensator is not cancelled by zeros in the system then the lag-lead compensator increases the order of the system by two.

The lag-lead compensation is employed when improvements in both steady-state and transient response are required.

34. Draw the bode plot of lag-lead compensator.

Let, Gc (jω) = Sinusoidal transfer function of lag-lead compensator. The appropriate magnitude plot and phase plot of Gc (jω) are shown in the figure.