Course Code & Name: IC 6501 Control Systems
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Prepared by: P.Nedumal Pugazhenthi ASP/EEE

Two Mark Questions and answers Unit wise

UNIT-I SYSTEMS AND THEIR REPRESENTATION

1. Define system.
   When a number of elements or components are connected in a sequence to perform a specific function, the group thus formed is called a system.
2. Define control system.
   When the output quantity is controlled by varying the input quantity the system is called control system.
3. Define open loop system.
   The control systems in which the output has no effect upon the input quantity are called open-loop control system.
4. Define closed loop system?
   Control systems in which the output has an effect upon the input quantity in such a manner as to maintain the desired output value are called closed loop systems.
5. Define transfer function.
   The ratio between the Laplace transform of output and Laplace transform of input is called transfer function.
6. What is negative feedback?
   If the overall gain of the s/m decreases, then it is called negative feedback.
7. State Newton's second law of forces.
   It states that the sum of applied forces is equal to the sum of opposing forces acting on a body.
8. Define block diagram.
   A block diagram of a system is a pictorial representation of the functions performed by each component and of the flow of signals.
9. What are the elements of block diagram?
   The elements of block diagram are
   1. Block
   2. Summing point
   3. Branch point
10. Define signal flow graph.
    A signal flow graph is a diagram that represents a set of simultaneous linear algebraic equations.
11. Define node.
    A node is a point representing a variable or signal.

12. Define input node.
    The node which has only outgoing branches are called input node. This is also known as source node.
13. Define output node.
    The node which has only incoming branches are called output node. This is also called as Sink node.
14. Define non-touching loops.
    If the loops do not have a common node then they are said to be non-touching loops.
15. Give some basic properties of signal flow graph.

    1. It is applicable to linear systems only.
    2. A node in the signal flow graph represents the variable or signal.
    3. The signal flow graph of system is not unique.

16. Compare open loop and closed loop system.

Open loop	Closed loop
Inaccurate and unreliable.	Accurate and reliable
Simple and economical	Complex and costlier.
Stable	Great efforts are needed to design a stable system.

    .
17. Mention the electrical analogous of simple thermal system.
    The electrical analogous of simple 1st order thermal system is RC parallel circuit
18. What is the effect of positive feedback on stability?
    The positive feedback increases the error signal and drives the output to instability. But sometimes the positive feedback is used in minor loops in control systems to amplify certain internal signals or parameters.
19. What are the characteristics of negative feedback?
    - Accuracy in tracking steady state value.
    - Rejection of disturbance signals.

20. Write the analogous electrical elements in force-voltage analogy for the elements of mechanical translational system.
    Force, F $\rightarrow$ Voltage, V
    Velocity, v $\rightarrow$ Current, I
    Displacement, x $\rightarrow$ Charge, q
    Mass, M $\rightarrow$ inductance, L
    Stiffness, K $\rightarrow$ Capacitance, C
    Frictional coefficient, B $\rightarrow$ Resistance, R

21. What are the advantages and disadvantage of open loop systems?

Advantages of open loop systems

1. The open loop systems are simple and economical
2. The open loop systems are easier to construct
3. Generally, the open loop systems are stable

Disadvantages of open loop systems are

1. The open loop systems are inaccurate and unreliable
2. The changes in the output due to external disturbances are not corrected automatically

22. What are the advantages and disadvantages of closed loop systems?

The advantages of closed loop systems are

1. The closed loop systems are accurate
2. The closed loop are accurate even in the presence of non- linearities
3. The sensitivity of the systems are accurate even in the presence of non- linearities

The advantages of closed loop systems are

1. The closed-loop systems are complex and costlier
2. The feedback in closed loop system may lead to oscillatory response
3. The feedback reduces the overall gain of the system
4. Stability is a major problem in closed loop system and more care is needed to design a stable closed loop system

23. Give some examples of control system or List Few Applications of Control Systems

The examples of control systems are

(i) Temperature control system
(ii) Traffic control system
(iii) Numerical control system
(iv) Position control system

24. What are Analogue systems?

Systems whose differential equations are of identical form are called analogous system.

25. What is Servo Mechanism?

A Servo Mechanism is a feed back control system used to Control position (or) its derivative. It has the following essential features.

1. It is a closed loop system
2. It is used to control position, velocity (or) Acceleration
3. Its characteristics include - Automatic control, Remote operation - Fast response, High Accuracy

26. Define order of a system.

The highest power of the complex variables 'S' in the denominator of transfer function is called as the order of a system.

27. Give the properties of signal flow graph.

1. The algebraic equations which are used to construct signal flow graph must be in the form of cost and effect relationships.
2. Signal flow graph is applicable to linear systems.
3. A node in the signal flow graph represents the variable (or) signal.
4. A branch indicates the functional dependence of one signal on the other.

28. What are the basic components of automatic control systems?
    The basic components of automatic control systems are the following.
    (1) Error detector
    (2) Amplifier and controller
    (3) Actuator
    (4) Plant
    (5) Sensor
29. What are the different types of control systems?
    (i) Open loop control systems
    (ii) Closed loop control systems
    (iii) Linear and Non linear control systems
    (iv) Time Variant and time invariant control systems

UNIT-II **TIME RESPONSE**

1. What do you mean by time response of the system?
   It is the output of closed loop system as a function of time. It is denoted by c(t).
2. What are standard test signals? The standard test signals are
   - Step input
   - Ramp input
   - Parabolic input
   - Impulse input
   - Sinusoidal signals
3. Define ramp signal.
   The ramp signal is a signal whose value increase linearly with time from an initial value of zero
4. Define impulse signal.
   A signal which is available for very short duration is called impulse signal.
5. Define order of a system.
   The order of the system is given by the order of the differential equations governing the system
6. Define damping ratio.
   The damping ratio is defined as the ratio of the actual damping to the critical damping.

7. How the system is classified based on depending ratio?
   The system is classified into 4 types
   i. Undamped system
   ii. Underdamped system
   iii. Critically damped system
   iv. Over damped system
8. What are time domain specifications?
   The time domain specifications are Delay time Rise time Peak time Maximum overshoot Setting time, ts
9. Define delay time.
   It is the time taken for response to reach 50% of the final value, for the very first time
10. Define risetime.
    It is the time taken for the response to raise from 0 to 100% for the very first time.
11. Define Peaktime.
    It is the time taken for the response to reach the peak value for the very first time.
12. Define peak overshoot.
    It is defined as the ratio of the maximum peak value measured from final value
13. Define settling time.
    It is defined as the time taken by the response to reach and stay within a specified error.
14. Define steady state error.
    The steady state error is the value of error signal e(t), when t tends to infinity.
15. What is the drawback of static error coefficient?
    The drawback in static error coefficients is that it does not show the variation of error with time and input should be a standard input.
16. 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 tends to infinity is called steady state response.
17. What will be the nature of response of a second order system with different types of damping?
    (1) Undamped system - Oscillatory
    2) Underdamped system - damped oscillatory
    3) Critically damped - exponentially rising
    4) Over damped - exponentially rising
18. What is type number of a system? What 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.
19. What are static error constants?
    The kp, kv and ka are called static error constants. These constants are associated with steady state error in a particular type of a system and for a standard input.

20. Mention two advantages of generalized error constants over static error constants.
    1. Generalized error series gives error signal as a function of time.
    2. Generalized error constant is used to determine the steady state error for any type of input.
21. What is the effect on system performance when a proportional controller is introduced in
    a system?
    1. It improves the steady state tracking accuracy relative stability and disturbance signal rejection
    2. Increases loop gain of the system.

22. What is the disadvantage in proportional controller?
    The disadvantage is that it produces a constant steady state error.
23. What is the effect of PI controller on the system performance?
    1. The PI controller increases the order of the system by one, which results in reducing the steady state error.
    2. The system becomes less stable
24. What is the effect of PD controller on the system performance?
    The effect of PD controller is to increase the damping ratio of the system and so the peak overshoot is reduced.
25. 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
26. What is a proportional Controller?
    The controller which produces the output signal in proportional to the error signal is called a proportional controller.
27. What is a PI Controller?
    PI Controller is a proportional plus integral controller which produces on output signal consisting of two terms – one proportional to error signal and other proportional to the integral of the error signal
29. 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 error signals.
30. What in the type and order of the given system?
    - The number of poles lie at origin of S-plane gives the types of system.
    - The highest power of the complex variables ‘S’ in the denominator of transfer function is called as the order of a system.

UNIT-III **FREQUENCY RESPONSE**

1. Define frequency response.
   The frequency response is the steady state response of a system when the input to the system is a sinusoidal signal.
2. Write any three advantages of frequency response analysis.
   1. The absolute and relative stability of the closed loop system can be estimated from the knowledge of their open loop response.
   2. The practical testing of systems can be easily carried with available sinusoidal signal generators and precise measurement equipments.
   3. The transfer function of complicated system can be determined experimentally by frequency response plots
3. What are frequency domain specifications?
   1. Resonant peak
   2. Resonant frequency
   3. Bandwidth
   4. Cut-off rate
   5. Gain margin
   6. Phase margin
4. Define resonant peak.
   The maximum value of the magnitude of closed loop transfer function is called the resonant peak.
5. Define resonant frequency.
   The frequency at which the resonant peak occurs is called resonant frequency.
6. Define bandwidth.
   The bandwidth is the range of frequency for which the system gain is more than -3dbr.
7. Define cut-off frequency.
   The frequency at which the gain is -3db is called cut-off frequency.
8. Define gain margin
   The gain margin is defined as the reciprocal of the magnitude of open – loop transfer function at phase cross over frequency. (Or) The maximum gain that can be varied in the open loop transfer function to bring the system to the verge of instability
9. Define phase margin
   The phase margin is the amount of additional phase lag at the gain cross over frequency required to bring the system to the verge of instability
10. What are the graphical techniques available for frequency response analysis?
    - Bode plot
    - Polar plot
    - Nichols plot
    - M and N circles
    - Nichols chart.
11. What the two graphs are of bode plot?
    A plot of the magnitude of a sinusoidal transfer function Vs log ω
    A plot of the phase angle of a sinusoidal transfer function Vs log ω
12. What the advantages are of bode plot?
    Multiplication of magnitudes can be converted into addition.
    An approximate log-mag curve can be sketched.

13. What do you mean by polar plot?
    The polar plot of a sinusoidal transfer function G(jw) is a plot of the magnitude of G(jw) is a plot of the magnitude of G(jw) Vs the phase angle of G(jw) on polar coordinates as ω is varied from zero to infinity.
14. Define phase cross over frequency.
    It is the frequency at which the phase of G(jω) is -180
15. Define gain cross over frequency.
    It is the frequency at which the magnitude of G(jω) is unity
16. 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
17. 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 of S plane.
18. 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.
19. What is non – minimum phase transfer function?
    A transfer function which has one or more zeros or poles in the right half S-plane is known as non- minimum phase transfer function.
20. State the conditions for stability of the system
    - If gain cross over frequency < phase cross over frequency the system is stable
    - If the gain cross over frequency > phase cross over frequency, the system is unstable
    - If gain cross over frequency = phase cross over frequency, the system is marginally stable.
21. What should be the values of GM and PM of a good system?
    An adequate gain margin of 6db and phase margin of about 30 degree is generally considered good enough for a good system
22. How to improve the GM and phase margin?
    The GM and PM can be improved by adding compensating networks.
23. What are the advantages and disadvantages of frequency response Analysis.

Advantages

1. The design and parameter adjustment of the open loop Transfer function for the given closed loop requirement is carried out easily
2. The effect of noise can be easily visualised in frequency response analysis.

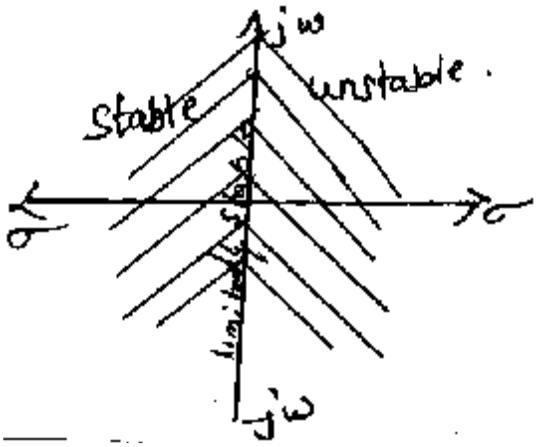
Disadvantage

1. The frequency response test is not recommended for the system with large time constant.
2. It cannot be performed on non-interruptible system.

24. The open loop Transfer function of a unity feedback control system is given by following. What are the phase cross over frequency and gain Margin Value.

UNIT-IV STABILITY AND COMPENSATOR DESIGN

1. **What is meant by asymptotic stability concept?**
   In the absence of the input, the output tends towards zero (the equilibrium state of the system) irrespective of initial conditions
2. **What are the regions of root locations for stable, unstable and limitedly stable systems?**
   1. If the poles lie on the LHS of S plane system is stable
   2. If any pole lies on the RHS of the S plane the system is
   3. I any pole lie on the jw axis (imaginary axis) the system is limitedly stable.
3. **Draw the regions of root – locations for stable, unstable and limitedly stable systems**



4. **What is the measure of Relative stability?**
   If indicates the closeness of the system to stable regions. It is an indication of the strength or degree of stability.
5. **What is the necessary condition for stability of the system in characteristic equation?**
   a) All the coefficients of the characteristic equation should be positive.
   b) There should be no missing terms in characteristic equation.
6. **What is absolutely stable system?**
   If a system output is stable for all variations of its parameter then the system is called absolutely stable system.
7. **What is conditionally stable system?**
   If a system output is stable for a limited range of variations of its parameters then the system is called conditionally stable system.
8. **Define BIBO Stability.**
   A linear relaxed system is said to have BIBO stability if every bounded (finite) input result in a bounded (finite) output.

9. **What is a characteristic equation?**

The denominator polynomial of C(S) / R(S) is the characteristic equation of the system.

10. What is the necessary and sufficient condition for stability?

The necessary and sufficient condition for stability is that all of elements in the first column of the south array should be positive.

11. 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 be positive. If the 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.

12. What is auxiliary polynomial?

In the construction of routh array a low 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 zero only. This even polynomial factor is called auxiliary polynomial. The coefficients of auxiliary polynomial are given by the elements of the row just above the row of all zero.

13. What is Nyquist stability criterion?

If G(S) H(S) contour in the G(S) H(S) plane corresponding to Nyquist contour in s-plane encircles the point –1+j0 in the anti-clockwise direction as many times as the number of right half S-plane poles of G(S) H(S). Then the closed loop system is stable

14. What is Root locus?

The path taken by a root of characteristic equation when open loop gain K is varied from O to ∞ is called root locus.

15. What are asymptotes? How will you find the angle of asymptotes?

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

Angles of asymptotes = ± 180 (2q+1)/(n-m);

q= 0, 1, 2, ...(n-m)

16. What is centroid? How the centroid is calculated?

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

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

17. What is breakaway and break-in point? How to determine them?

- At breakaway 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 breakaway 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 equation dk/ds = 0. The roots of dk/ds=0 are breakaway or break-in point provided for this value of root the gain K should be positive and real.

18. How to find the crossing point of root locus in imaginary axis?

- Method (i) By routh Hurwitz criterion
- Method (ii) By lettings the real S= jw in the characteristic equation and separate the real and imaginary part. These two equations are equated to zero.

Solve the two equations for w and k. The value of w gives the point where the root locus crosses. Imaginary axis and the value of K is gain corresponding to the crossing point.

19. What is dominant pole?

The dominant pole is a pair of complex conjugate pole which decides transient response of the system. In higher order system 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.

20. What are the applications of root locus?

1. It is used to design a closed loop Control system.
2. It is used to do the stability analysis of closed loop system.

21. Name some of the technique to connect compensator with the system

1. Cascade or series compensator
2. Feedback compensator
3. Load Compensator
4. Feed-Forward Compensator

22. What is the minimum performance specification to design linear system design?

1. Set of specifications in time domain or frequency domain such as peak overshoot, gain margin, phase margin, settling time, steady state-error etc.,
2. The other method is by optimality of a certain function.

23. What is the need of using compensators in control system?

- If the system is unstable the compensators are needed to stabilize the system
- If the system is stable the compensators are needed to obtain desired performance

24. What is cascade compensation?

The compensation network inserted in the forward path is called cascade compensation

25. What is feedback compensation?

The compensation network inserted in the feedback path of the system is called feedback compensation.

26. What are the basic types of compensators?

i. 1.Electrical 2.Mechanical
ii. 3.Pneumatic 4.Hydraulic type of device

27. How electrical compensators are classified.

iii. 1.Lead networks
iv. 2.Lag networks
v. 3.Lag-Lead Networks

28. What is the contribution of lead compensating network in control system?

vi. The lead compensating network contributes phase lead frequency response characteristics which appreciably improves the transient response and to a small extent the steady state performance.

29. Which technique is the most suitable when the system is used to meet the time domain specifications?

vii. Root Locus technique is the most suitable when the system is used to meet the time domain specifications.

30. What is the contribution of lag compensating network in control system?

viii. It attenuates the magnitude curve and contributes more phase lag at the gain cross over frequency.

31. What is the contribution of lead-lag compensating network in control system?

ix. It provides increased bandwidth thus improving the time response of the system at the same time providing additional forward path gain which will give improved steady-state error.

32. What is the need of Lead compensation?

For system with mechanical output, suitable compensation is provided to damp out the oscillations in the system. This is achieved by providing additional fiction in the existing system.

33. 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

1. Nature of signals in the system .
2. Power levels at various points.
3. Components available .
4. Designer's choice.
5. Economic Considerations.

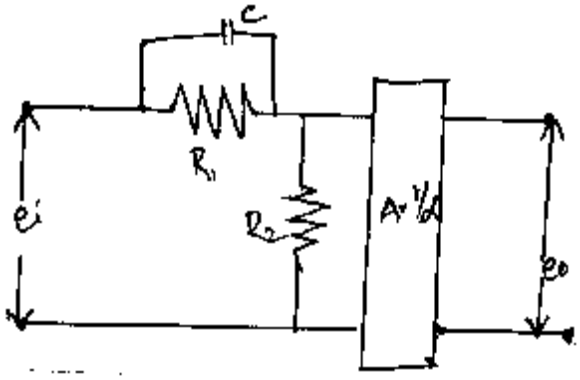
34. Discuss the effect of adding a pole to open loop transfer function of a system.

- 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.

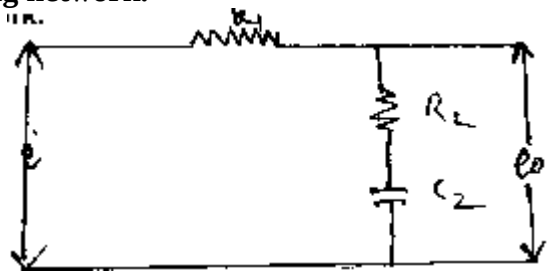
35. Discuss the effect of adding a zero to open loop transfer function of a system.

- 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 half of splane then the effect of zero on the transient response will be negligible.

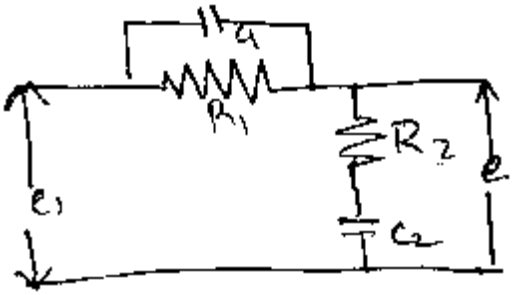
36. Draw the phase – lead network with amplifier.



37. Draw the Electric lag network.



38. Draw the Electric lag – lead network



UNIT-V **STATE VARIABLE ANALYSIS**

1. What is state?
   The state of dynamic system is defined as a minimal set of variables such that the knowledge of these variables at t =to together with the knowledge of inputs t > 0 completely determine the behavior of the system for t > to.
2. What is state variable?
   The variables involved in determining the state of dynamic system are called state variables. Generally x1(t),x2(t),x3(t)…….xn(t) are called state variables.
   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.
3. What is state vector?
   The state vector x(t) is the vector sum of all the state variables.
4. What is state space?
   The space whose coordinate axes are nothing but the 'n' state variables with time as the implicit variable is called state space.
5. 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(t0) at any other desired state X(t), in specified finite time by a control vector U(t).
   A general nth order multi-input linear time invariant system. dX/dt = AX +Bu. Is completely controllable if and only if the rank of the composite matrix
   Qc = [B:AB : A^2B:…….. :$A^{n-1}B$] is n
6. 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.
   A general nth order multi-input multiple output linear time invariant system .
   dX/dt = AX +Bu. Y= CX is completely observable if rank of the composite matrix Qc = [$C^{T:}A^TC^T$:…….. :$(A^T)^{n-1}B$] is n
7. What are the advantages of state space analysis?
   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 multiple output systems. The state variables selected need not necessarily be the physical quantities of the system.
8. What are phase variables?
   The phase variables are defined as the state variables which are obtained from one of the system variables and its derivatives.

9. Write the general form of state variable matrix.
   The most general state-space representation of a linear system with m inputs, p outputs and n state variables is written in the following form:
   dx/dt= AX + BU

Y = CX + DU
Where
X = 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.

10. Write the relationship between z-domain and s-domain.
    All the poles lying in the left half of the S-plane, the system is stable in S-domain. Corresponding in Z-domain all poles lie within the unit circle.
11. 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.
12. Write the properties of state transition matrix.
    The following are the properties of state transition matrix
    $\Phi(0) = eAx0 = I$ (unit matrix).
    $\Phi(t) = e^{At} = (e^{-At)^{-1}} = [\Phi(-t)]^{-1}$.
    $\Phi(t1+t2) = e^{A(t1+t2)} = \Phi(t1)\,\Phi(t2) = \Phi(t2)\,\Phi(t1)$
13. 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
14. State the condition for controllability by Gilbert's method.
    Case (i) when the eigen values are distinct
    Consider the canonical form of state model shown below which is obtained by using the transformation X=MZ.
    dz/dt= ΛZ + U
    Y=Z + DU
    Where,
    $\Lambda = M^{-1}AM$; C'= CM ,
    B'= M^{-1}B and
    M = Modal matrix.
    In this case the necessary and sufficient condition for complete controllability is that, the matrix must have no row with all zeros. If any row of the matrix is zero then the corresponding state variable is uncontrollable.
    Case (ii) when eigen values have multiplicity In this case the state modal can be converted to Jordan canonical form shown below
    dz/dt= JZ + U Y=Z + DU
    Where,
    J = M-1AM
    In this case the system is completely controllable; if the elements of any row of that correspond to the last row of each Jordan block are not all zero
15. State the condition for observability by Gilbert's method.

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

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 has all zeros then the corresponding state variable is not observable.

16. 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 vice versa.