EC3351 CONTROL SYSTEMS-QUESTION BANK

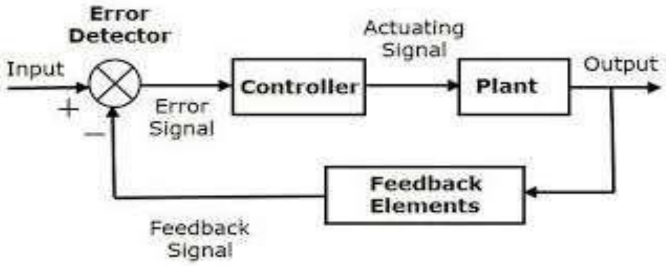
UNIT I – SYSTEMS COMPONENTS AND THEIR REPRESENTATIONS

Control System: Terminology and Basic Structure-Feed forward and Feedback control theory Electrical and Mechanical Transfer Function Models-Block diagram Models-Signal flow graphs models-DC and AC servo Systems-Synchronous -Multivariable control system

PART - A

1. **Define control system. (Nov 2016)**

A control system manages commands, directs, or regulates the behavior of other devices or systems using control loops. A control system is a system, which provides the desired response by controlling the output



2. **Define open loop and closed loop system. (May 2011, Nov 2011, Nov 2017)**

Open loop system: An open-loop system is a type of control system in which the output of the system depends on the input but the input or the controller is independent of the output of the system. These systems do not contain any feedback loop and thus are also known as non-feedback system. In the presence of disturbances, an open loop control system will not perform the desired task because when the output changes due to disturbances, it is not followed by changes in input to correct the output.

Closed loop system: The control system in which the output quantity has an effect on the input quantity so as to maintain the desired output value is called closed loop control system. In closed loop system (also feedback control system) ,the error signal which is difference between input signal and feedback signal is fed to the controller so as to reduce the error and bring the output of the system to the desired value

3. **Give the comparison between (Differentiate) open loop system and closed loop system. (May 2010, Nov 2010, Dec 2014, May 2016,Nov 2015, May 2017)**

S.No.	**Open loop system**	**Closed loop system**
1	The output quantity has no effect upon the input quantity.	The output has an effect upon the input quantity so as to maintain the desired output value
2	Inaccurate and unreliable	Accurate and reliable
3	Simple and economical	Complex and costlier
4	The changes in output due to external disturbances are not corrected automatically.	The changes in output due to external disturbances are corrected automatically
5	They are generally stable	Great efforts are needed to design a stable system.
6	In the case of Bandwidth the frequency at which the gain falls by 3 dB	The Frequency at which the magnitude of the closed loop gain does not fall below -3dB
7	Examples:Stepper Motor, Traffic light	Temperature control system, Pressure control system, speed control system

4. **What are the properties of signal flow graphs? (May 2012)**

- The Linear algebraic equations which are used to construct signal flow graph must be in the form of cause and effect relationship.
- Signal flow graph is applicable to linear systems only.

Applicable only for Time-Invariant systems

5.	**What is Signal Flow Graph ?** A node in the signal flow graph represents the variable or signal. A node adds the signals of all incoming branches and transmits the sum to all outgoing branches. A mixed node which has both incoming and outgoing signals can be treated as an output node by adding an outgoing branch of unity transmittance
6.	**What is the principle of operation of closed loop systems** • The closed loop system compares the actual output measured by the sensor with the set point and produces the error signal or actuating signal. The controlled variable has to be kept at certain value regardless of any disturbing influences acting on the system.
7.	**How are feedback control systems classified?** (i) Negative feedback system where output and set point values are subtracted used in Amplifiers Positive feedback system where output and set point values are added used inoscillators
8.	**What are the characteristics of negative feedback? (May 2014)** The characteristics of negative feedback are as follows: • Accuracy in tracking steady state value • Rejection of disturbance signals (ii) Low sensitivity to parameter variations Reduction in gain at the expense of better stability
9.	**Why negative feedback is invariably preferred in a closed loop system?** The negative feedback results in better stability in steady state and rejects any disturbance signals. It also has low sensitivity to parameter variations. Hence negative feedback is • preferred in closed loop systems.
10.	**Give two advantages of closed loop control over open loop control.(May 2019)** Advantages/Merits • More accurate • It compensates for disturbances It greatly improves the speed of its response
11.	**What is called feedback control system? Give an example.(May 2018)(Or)** **Define closed loop control system with a suitable example.(Dec 2018)** The feedback control system is also known as closed loop control system or Automatic control system. The output is feedback to the input for correction. The feedback path element samples the output and converts it to signal of same type of reference signal. Example: Automatic Traffic control system

12. **Distinguish between feed forward control system and feedback control systems.(NOV 2019)**

S.NO	FEED FORWARD CONTROL SYSTEM	FEEDBACK CONTROL SYSTEMS.
1.	Feedforward control does not check how the adjustments of inputs worked in the process. So, it is referred to as OPEN LOOP CONTROL.	Feedback control measures the output and verifies the adjustment results. So, it is called as CLOSED LOOP CONTROL.
2.	Feedforward control takes corrective action before the disturbances entering into the process.	Feedback control takes corrective action only after the disturbances has affected the process and generated an error.
3.	Feedforward control has to predict the output as it does not measure output. So, it is sometimes called as PREDICTIVE CONTROL.	The feedback control reacts only to the process error (the deviation between the measured output value and set point). So, it is called as REACTIVE CONTROL.
4.	The feedforward control does not affect the stability of the system.	The feedback control may create instability of the system.
5.	The feedforward control requires to measure and control more inputs.	The feedback control requires less measuring instruments and control equipment's comparatively.
6.	The variables are adjusted on the basis of knowledge.	The variables are adjusted on the basis of errors.

13. **Name any two dynamic models used to represent control systems. (May 2013)**

Dynamic models used to represent control system are

- Differential Equation Modelling
- Transfer function model which uses Laplace transformation with differential Equations which does not uses initial values
- State space model which also uses differential models which uses initial values

14. **Define the Transfer function of a system and mention its applicability in control system (Nov 2010, Nov 2013, Nov 2017)**

The Transfer function of a system is defined as the ratio between Laplace transform of the output and Laplace transform of the input when initial conditions are zero. It is used to analyses the system characteristics.

$$\text{transferfunction} = \left.\frac{\text{laplacetransformof theoutput}}{\text{laplacetransformof theinput}}\right|_{\text{Zeroinitial conditions}}$$

15. **State the properties of a linear system.**

It obeys the principle of superposition and homogeneity. Principle of superposition implies that if a system model has responses $Y_1(t)$, $Y_2(t)$ to any two inputs $X_1(t)$, $X_2(t)$ respectively, then the system response to the linear combination of these inputs $\alpha_1 X_1(t) + \alpha_2 X_2(t)$ is given by the linear combination of the individual outputs, i.e., $\alpha_1 Y_1(t) + \alpha_2 Y_2(t)$ where $\alpha 1$, $\alpha 2$ are constants.

Homogeneity states that the output of a linear system is always directly proportional to the Input of the system

16. **What are the basic elements of closed loop control system? (Or) What are the basic components of automatic control system?**

- Error detector or comparator
- Amplifier and Controller
- Plant or System to be controlled

	• Sensor or feedback system
17.	**State the laws governing mechanical rotational elements.** The laws governing mechanical rotational elements are Newton's law and D'Alembert's principle. Newton's law states that the sum of torques acting on a body is zero. Alembert's law states that the sum of all Torque acting on the inertial is equal to zero. with J as the moment of Inertia, K as the torsional spring and B as the Dashpot
18.	**State Mason's Gain formula. (May 2013, May 2014, Dec 2014, May & Nov 2015 May 2016, May 2017)** Mason's gain formula is given by, $T = \frac{1}{\Delta}\sum_k P_k \Delta_k$ P_k = path gain of k^{th} forward path. Δ = 1- (sum of individual loop gains) + (sum of gain of all combinations of two non-touching loops) – (sum of gain product of all combinations of three non-touching loops) Δ_k = Δ of that part of graph not touching the k^{th} forward path
19.	**What are the basic elements used for modeling mechanical translational system?(Nov 2016)** The basic elements used for modeling mechanical translational system which move along a straight line are Mass(M), Damper (B) and Spring(K)
20.	**What are the basic elements used for modeling mechanical rotational system?** The basic elements used for modeling mechanical rotational system are Moment of inertia (J), dashpot with rotational frictional coefficient (B) and torsional spring with stiffness (K).

UNIT II- TIME RESPONSE ANALYSIS

Transient response-steady state response-Measures of performance of the standard first order and second order system-effect on an additional zero and an additional pole-steady error constant and system- type number-PID control-Analytical design for PD, PI,PID control systems

PART - A

1.	**What is the necessity for standard test signals in the analysis of control systems?** In many control systems the command signals are not known fully ahead of time. It is difficult to express the actual input signals mathematically by simple functions. To know the behavior of the system in advance the standard test signals are used in the analysis of control systems. The standard signals are Impulse, Step, ramp ,Parabolic
2.	**List the standard test signals used in time domain analysis. (May 2016, Nov 2017)** The standard test signals used in time domain analysis are • Unit step input • Unit Impulse input • Unit ramp input • Unit parabolic input
3.	**What is the difference between type and order of a system?**

S.No	**Type of a system**	**Order of a system**

1	Type no is given by number of poles of loop transfer function at origin of S=0	Order is given by the number of poles of transfer function
2	It is specified for loop transfer function G(s)H(s)	It is specified for any transfer function (open loop or closed loop transfer function)

4. **What are type 0 and type 1 system? (May 2014)**

Type 0 systems – there are no poles of loop transfer function that lies at origin.
Type 1 system – it has only one pole of loop transfer function lies at origin.

5. **What is the positional error coefficient?**

The positional error constant $K_p = \lim_{s \to 0} G(s)H(s)$. Here G(s)H(s) is the loop transfer function.

The steady state error in type – 0 system for unit step input is given by $\frac{1}{1 + Kp}$

6. **For the system with the following transfer function, determine type and order of the system. (Nov 2009)**

i) $G(s)H(s) = \dfrac{(s+4)}{(s-2)(s+0.25)}$ **ii)** $G(s)H(s) = \dfrac{200}{s(s^2+20s+200)}$

Type of a system:
Type no is given by number of poles of loop transfer function at origin of S-plane.
Order of a system:
Order is given by the number of poles of transfer function.
i) Type =0, Order=2 ii)Type =1, Order=3

7. **Distinguish between steady state response and transient response.**

Transient response:
Transient response is the time response of the system when the input changes from one state to another. Transient response is temporary and will die out soon
Steady State Response:
Steady state response is the time response of the system when time tends to infinity. It is the behaviour of the system after an external input is applied to that system

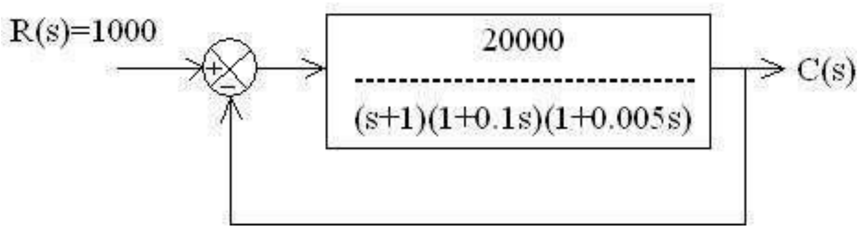
8. **What are time domain specifications? (Dec 2014, Nov 2016)**

The time domain specifications are Peak time (t_p), Delay time (t_d), Rise time (t_r), Maximum over shoot ($\%M_p$), and Settling time (t_s)

9. **Define delay time.**

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

10. **The block diagram shown in fig. represents a heat treating oven. The set point is 1000°C. What is the steady state temperature? (May 2010)**



At steady state the system reaches its final value which is the set point. Here the set point is 1000°C

11. **Define rise time. (or) What is meant by rise time? (May 2014, Nov 2016)**

For underdamped system: Rise time is the time taken for the response to rise from 0% to 100% for the very first time.
For overdamped system: Rise time is the time taken by the response to rise from 10% to 90%.
For critically damped system: Rise time is the time taken for the response to rise from 5% to 95%.

Rise Time $t_r = \dfrac{\pi - \theta}{\omega_d} = \dfrac{\pi - \tan^{-1}\dfrac{\sqrt{1-\xi^2}}{\xi}}{\omega_n\sqrt{1-\xi^2}}$

Where
ω_d is the damped frequency; ω_n is the natural frequency; ξ is the damping ratio;

12. **Define Peak time (T_p) (Nov 2016)**

Peak time is the time taken for the response to reach the peak value for the very first time. (or) it is the time taken for the response to reach the peak overshoot.

Peak time= $t_p = \dfrac{\pi}{\omega_n\sqrt{1-\xi^2}}$

Where

	ω_n is the natural frequency; ξ is the damping ratio;
13.	**What are static error constants?** The K_p, K_v and K_a are called static error constants. These constants are associated with Steady State error in a particular type of system and for a standard input.
14	**Define maximum peak overshoot.** Maximum Peak overshoot is defined as the ratio of maximum value measured from thesteady state vale to the steady state value. $\% \text{Peak overshoot}, \%M_p = \frac{c(t_p) - c(\infty)}{c(\infty)} \times 100$ Where $c(t_p)$ is the output at t_p; $c(\alpha)$is the output at infinity time.
16.	**How the system is classified depending on the value of damping?** Case 1 :Undamped system, $\xi = 0$ Case 2 :Underdamped system, $0 < \xi < 1$ Case 3 : Critically damped system, $\xi=1$Case 4 :Overdamped system, $\xi>1$
17.	**Why is 'under damping' preferred to over damping in control systems?** 'Under damping' is preferred over damping, to achieve high response speed. That is the settling time is less for an under damped system compared to over damped systems, even though the oscillations are less in the later

18.Why derivative control action is never used alone?

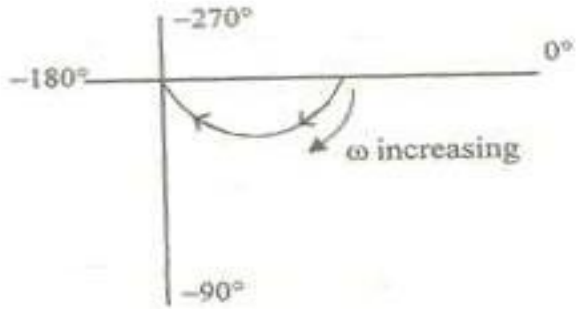
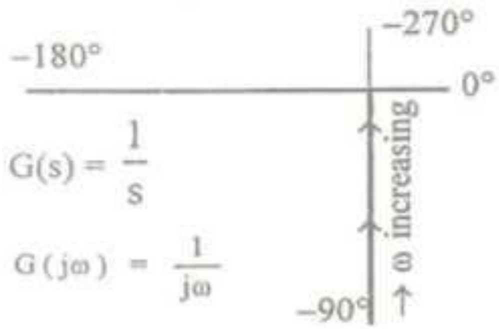
Since the derivative controller's output is directly proportional to the rate of change of errorsignal if it is used alone for a constant error signal it will not give any corrective action. With sudden changes in the system the derivative controller will compensate the output fast.A derivative controller will in general have the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response

19.What is the effect of Pl controller on the system performance? (Nov2013, Dec 2014,May 2016) 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.It Eliminates Offset
20.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. P controller is to decrease the steady state error of the system. As the proportional gain factor K increases, the steady state error of the system decreases. However, despite the reduction, P control can never manage to eliminate the steady state error of the system

UNIT 3

1.	**What are the frequency domain specifications? (Or) Name the parameters which constitute frequency domain specifications. (Nov 2011, May 2016)** The frequency domain specifications indicate the performance of the system in frequency domain, and they are Resonant peak(ω_p), Resonant frequency(ω_r), Band width(ω_b), Cut-off rate, Phase margin(γ) & Gain margin (k_g).
2.	**Define resonant peak and resonant frequency.** **Resonant peak (M_r):** The maximum value of the magnitude of closed loop transfer function is called resonant peak. A large resonant peak corresponds to a large overshoot in transient response. The resonant peak, $M_r = M_r 1/2\xi\sqrt{1-\xi^2}$ Where M_r is the resonant peak, ξ is the damping ratio. **Resonant frequency (ω_r) :** The frequency at which the resonant peak occurs is called resonant frequency. This is related to the frequency of oscillation in the step response and thus it is indicative of the speed of transient response. The resonant frequency, $\omega_r = \omega_n \sqrt{1-2\xi^2}$ Where ω_r is the resonant frequency; ω_n is the natural frequency; ξ is the damping ratio.
3.	**What is meant by corner frequency in frequency response analysis? (May 2011, Nov 2012, May 2014)** The magnitude plot can be approximated by asymptotic straight lines. The frequencies corresponding to the meeting point of asymptotes are called corner frequencies. The slope of the magnitude plot changes at every corner frequency.
4	**Define phase margin. (Nov 2013, May 2014, Dec 2014, Nov 2016, May 2018)** The phase margin is defined as the amount of additional phase lag at the gain crossover frequency (ω_{gc}) required to bring the system to the verge of instability. Phase margin $\gamma = \phi_{gc} + 180°$ Where ϕ_{gc} is the phase angle of $G(j\omega)H(j\omega)$ at $\omega = \omega_{gc}$
5	**Define phase cross over frequency.** The phase cross over frequency is the frequency at which the phase of open loop transfer function is -180°.
6.	**Define the term Gain Margin.(Dec 2014, Nov 2015, May 2017, May 2018)** The gain margin, K_g is defined as the value of gain, to be added to system in order to bring the system to the verge of instability. The gain margin is given by the reciprocal of the magnitude of open loop transfer function at phase cross over frequency. The phase cross over frequency is the frequency at which the phase is -180°. Gain margin $Kg = \frac{1}{\lvert G(j\omega_{pc})\rvert}$ The gain margin in dB can be expressed as

	$K_g \, in dB = 20\log(K_g) = 20\log \dfrac{1}{G(j\omega_{pc})}$
7	**What is all pass systems and non-minimum phase transfer function?** All pass systems: An all pass system is a system whose frequency magnitude response is constant for all frequencies and the transfer function will have anti symmetric pole zero pattern (i.e. for every pole in the left half of s – plane, there is a zero in the mirror image position with respect to imaginary axis. Non-minimum phase transfer function: A transfer function, which has one or more zeros in the right half s – plane is known as non-minimum phase transfer function.
8.	**What is bode plot? State the advantage of Bode plot (Nov 2015).** **The bode plot is a frequency response plot of the transfer function of a system. It consists of two plots – magnitude plot and phase plot.** **Magnitude plot: Plot between magnitude in dB and log ω for various values of ω .** **Phase plot: Plot between phase in degrees and log ω for various values of ω .** **Usually both the plots are plotted on a common X-axis in which the frequencies are expressed in logarithmic scale.** **Advantages:** • **The approximate plot can be sketched quickly.** • **The frequency domain specifications can be easily determined.** • **The Bode plot can be used to analyse both open loop and closed loop system.**
9.	**Draw the polar plot of** $G(s) = \dfrac{1}{(1+sT)}$ **(May 2012)**

	
10.	**Draw the polar plot of an integral term transfer function. (May 2013)** 
11.	**What is Nichols chart?** When constant M and N circles are superimposed on log magnitude and phase angle coordinates, the resulting chart is called as Nichol's chart. The Nichol's chart is very useful for determining the closed loop response from that of open loop.
12.	**State the uses of Nicholas chart. (May 2012,Dec 2014, May 2015, Nov 2016)** (i) It is used to find the closed loop frequency response from the open loop frequency Response. (ii) It is used to determine the frequency domain specifications (iii) The gain of the system can be adjusted to satisfy the given specification.
13.	**What is compensation and what are the types of compensators? (May 2009)** The compensation is the design procedure in which the system behaviour is altered to meet the desired specifications, by introducing additional device called compensator. The types of compensator are lag compensator, lead compensator, lag-lead compensator.
14.	**Discuss the effects of adding a pole to open loop transfer function of a system.** Addition of poles to the transfer function has the effect of pulling the root locus to the right, making the system less stable
15.	**Why compensators are necessary in feedback control system? (NOV 2019)** In feedback control systems compensation is required in the following situations. 1. When the system is absolutely unstable, then compensation is required to stabilize the system and also to meet the desired performance. 2. When the system is stable, compensation is provided to obtain the desired performance

16.	**Name the commonly used electrical compensating networks. (May 2009)** Lag network-Low pass filter, Lead network - high pass filter Lead-Lag network – Band pass filter
17.	**State the property of a lead compensator. (Nov2013, May 2015)** **The lead compensation increases the bandwidth and improves the speed of response. It also reduces the peak overshoot. If the pole introduced by the compensator is not cancelled by a zero in the system, then lead compensation increases the order of the system by one. When the given system is stable/unstable and requires improvement in transient state response then lead compensation is employed.**
18.	**Mention few applications of bode plot. (Nov 2015)** • **To determine stability of OP-AMP and Transistor.** • **Stability analysis of control system** • **Active filter circuits** • **The frequency domain specifications can be easily determined** • **The bode plot can be used to analyse both open loop and closed loop system.**

19.What is lag-lead compensation? (Nov 2009)

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

20 In a bode plot a Unity feedback system, the value of phase of G(jω) at the gain crossover frequency is -125°. What is the phase margin?(Dec 2018)

$$\gamma = 180° + \varphi_{gc}$$

$$\gamma = 180° - 125°$$

$$= 55°$$

UNIT IV – CONCEPTS OF STABILITY ANALYSIS

Concept of stability-Bounded - Input Bounded - Output stability-Routh stability criterion- Relative stability-Root locus concept-Guidelines for sketching root locus- Nyquist stabilitycriterion

PART - A

1.	**Define stability of a system. (May 2011, Nov 2011)** A linear time invariant system is said to be stable if the following conditions are satisfied. (i)When the system is excited by a bounded input, output is also bounded and controllable.(ii) In the absence of the input, output must tends to zero irrespective of initial conditions.

2.	**Define "bounded input bounded output (BIBO) stability".(Dec 2014, Nov 2017)** The first notion of system stability is for a linear time invariant system if the system is excited by a bounded input (i.e. for a finite input), the output should be bounded (i.e. finite output). Or in other words the impulse response g (t) is absolutely integrable.
3.	**Define asymptotic stability.** In the absence of the input, the output tends towards zero (the equilibrium state of the system) irrespective of initial conditions. This stability concept is known as asymptotic stability.
4.	**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.
5.	**What is the relation between stability and coefficient of characteristic polynomial?** If any one or more of the coefficients of characteristics polynomial are negative or zero, then some of the roots lies on right half of S plane. Hence the system is unstable. If the coefficients of characteristic equation are zero and the rest of the coefficients are positive then there is a possibility of the system to be stable provided all the roots are lying on left half of s-plane.
6.	**How are the locations of roots of characteristic equation related?** a) If all the roots of the characteristic equations have –ve real parts, the system is bounded Input bounded output stable. b) If any root of the characteristic equation has a +ve real part the system is unbounded and the impulse response is infinite and the system is unstable. c) If the characteristic equation has repeated roots on the jω axis the system is marginally stable d) If the characteristic equation has non-repeated roots on the jω axis the system is limitedly Stable e)double roots at the origin is unstable
7.	**What is root locus? (May 2012)** The locus of the closed loop poles obtained when the system gain 'K' is varied from
	$-\infty$ to $+\infty$.(change). The graphical representation in the complex **s**-plane of the possible locations of its closed-loop poles for varying values of a certain system parameter. The points that are part of the root locus satisfy the angle condition.
8.	**Comment on the stability of the system, when the roots of characteristic equation are lying on imaginary axis. (NOV 2019)** If the roots of the characteristic equation are lying on the imaginary axis then the system is marginally stable system. Here the term marginally stable means the system is in between the conditions of stability and instability.
9.	**What are pole and zero of a system?** The poles of a closed loop system are defined as the roots of the denominator polynomial of the transfer function of that system. It represents the physical dimension of a system The zeros of a closed loop system are defined as the roots of the numerator polynomial of the transfer function of that system. Zeros are the roots of numerator of given transfer function by making numerator is equal to 0

10.	**State the advantages of Nyquist plot.** (i) The Nyquist plot helps in determining the relative stability of the system in addition to the absolute stability of the system. It determines the stability of the closed-loop system from the open-loop transfer function without calculating the roots of the characteristic equation
11.	**What is meant by relative stability? (May 2014)** Relative stability is a quantitative measure of how fast the transients die out in the system. It may be measured by relative settling times of each root or pair of roots. Relative Stability gives the degree of stability or how close it is to instability
12.	**Why closed loop systems have a tendency to oscillate?** In closed loop system it has negative Feedback where the output is always compared with the input and the controller is going to take corrective action based on the difference between error and it has the tendency to oscillate when the gain in the controller increases.
13.	**What is the phase angle criterion in the root locus technique?** Phase angle criteria states that $\angle D(s) = \pm 180\ (2q+1)$ $\sum_{i=1}^{m}\angle(s+z_i)-\sum_{i=1}^{m}\angle(s+p_i)=\pm 180\ (2q+1)\quad q=0,1,2,...$
14.	**What is the advantage of using root locus for design? (Nov 2009)** To find out the potential closed loop pole location. It helps to design good compensator . The Root Locus Plot technique can be applied to determine the dynamic response of the system. This method associates itself with the transient response of the system and is particularly useful in the investigation of stability characteristics of the system
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 $=\frac{\pm 180\ (2q+1)}{n-m};\ q=0,1,2,3,....(n-m)$, n= no of poles and m = no of zeros
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, $Centroid=\frac{Sum of\ poles-Sum of\ zeros}{n-m}$ n=no of poles and m=no of zeros
17.	**Distinguish between relative stability and absolute stability.**

S.No	Relative stability	Absolute Stability

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

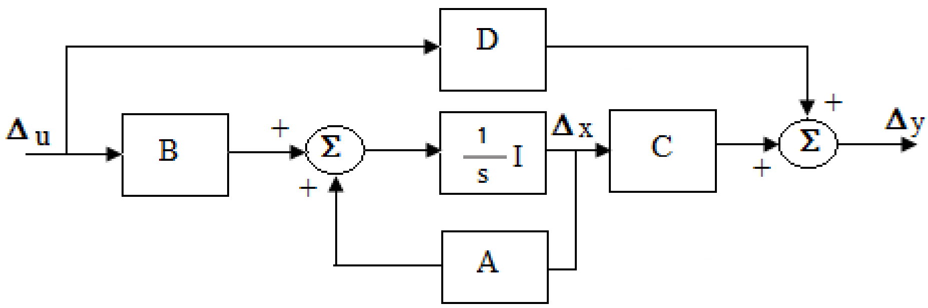
18.	**State the rule for obtaining breakaway point in root locus. (May 2011)** • To find the break away and break in points, form an equation for K from the characteristics equation, and differentiate the equation of K with respect to s. • Then find the roots of equation $\frac{dK}{ds}=0$ the roots of $\frac{dK}{ds}=0$ are breakaway or breakin points, provided for this value of root, the gain K should be positive real.
19.	**What is the main objective of root locus analysis technique.(May 2019)** The main objective of root locus plot is to obtain the transient response of feedback system for various values of open loop gain K and to determine sufficient condition for the value of 'K' that will make the feedback system unstable.
20.	**What is dominant pole?(Dec 2014, Nov 2016)** The dominant pole is a pair of complex conjugate poles 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.

UNIT V – CONTROL SYSTEM ANALYSIS USING STATE VARIABLE METHODS

State variable representation-Conversion of state variable models to transfer functions-Conversion of transfer functions to state variable models-Solution of state equations-Concepts of Controllability and Observability-Stability of linear systems-Equivalence between transfer function and state variable representations-State variable analysis of digitalcontrol system-Digital control design using state feedback

PART - A

1.	**Define state and state variable. (Nov 2012, May 2013, May 2016)** **State:** The minimum Number of initial conditions that must be specified at any initial time t_0 so that the complete behaviour of the system for $t\geq0$ is determined when the input is known**.** The state is the condition of a system at any time instant. **State variable:** State variables depend on the dynamic model selected to describe the physical system which can be described by nth order differential equations. A set of variables which describe the state of the system at any time instant are called state variables.

2.	**What is state space?(Nov 2015)** Sate space is the state of a system described by set of all possible variables in which the state vector X(t) can have at time ‘t’ forms the state space of the system.
3.	**Draw the block diagram of state space model.**
	
4.	**Define state model of nth order system? (Dec 2014, Nov 2017)** State model of nth order system: State equation : $\dot{X} = AX + BU$ $\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \vdots\\ \dot{x}_n\end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdot & a_{1n}\\ a_{21} & a_{22} & \cdot & a_{2n}\\ \vdots & \vdots & \vdots & \vdots\\ a_{n1} & a_{n2} & \cdot & a_{nn}\end{bmatrix}\begin{bmatrix}x_1(t)\\ x_2(t)\\ \vdots\\ x_n(t)\end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & \cdot & b_{1m}\\ b_{21} & b_{22} & \cdot & b_{2m}\\ \vdots & \vdots & \vdots & \vdots\\ b_{n1} & b_{n2} & \cdot & b_{nm}\end{bmatrix}\begin{bmatrix}u_1(t)\\ u_2(t)\\ \vdots\\ u_m(t)\end{bmatrix}$ [X is n x 1 state vector, U is m x 1 input vector, A is n x n square matrix and B is n x m matrix.] Output equation : $Y = CX + DU$ $\begin{bmatrix}y_1\\ y_2\\ \vdots\\ y_p\end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & \cdot & c_{1n}\\ c_{21} & c_{22} & \cdot & c_{2n}\\ \vdots & \vdots & \vdots & \vdots\\ c_{p1} & c_{p2} & \cdot & c_{pn}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ \vdots\\ x_n\end{bmatrix} + \begin{bmatrix} d_{11} & d_{12} & \cdot & d_{1m}\\ d_{21} & d_{22} & \cdot & d_{2m}\\ \vdots & \vdots & \vdots & \vdots\\ d_{p1} & b_{p2} & \cdot & b_{pm}\end{bmatrix}\begin{bmatrix}u_1(t)\\ u_2(t)\\ \vdots\\ u_m(t)\end{bmatrix}$ [Y is p x 1 output vector; C is p x n output matrix and D is p x m transmission matrix.]
5.	**What are hold circuits?** Hold circuits are devices used to convert discrete time signals to continuous time signals. Hold circuit maintains a value for a minimum specified period of time
6.	**What is input and output space?** The set of all possible values which the input vector u(t) can have at time ‘t’ forms the state space of the system. The set of all possible values which the output vector Y(t) can have at time ‘t’ forms the state space of the system.
7.	**What are the advantages of state space approach? (Nov 2011, May 2013)(Dec 2018)** a) The state space analysis is applicable to any type of systems. They can be used for modelling and analysis of linear and nonlinear systems, time variant and time invariant systems and multi input multi output systems. b) The state space analysis can be performed with initial conditions. c) The variables used to represent the system can be any variables in the system. d) Using this analysis the internal states of the system at any time instant can be predicted

8. **Compare the merits and demerits of realizing a given system in state variable and transfer function form. (Jan'14)**

Merits of transfer function:

1. It is useful for analyzing the effects of the input.
2. Transfer function can be used as a multiplier to obtain the forced response transform from the input transform.
3. transfer function is independent of the input function and the initial conditions

Demerits of transfer function form:

1. Transfer function is defined under zero initial zero conditions.
2. Transfer function is applicable to linear time invariant systems.
3. Transfer function analysis is restricted to single input and output systems.
4. Does not provide information regarding the internal state of the system.

Merits of State Variable form:

1. The state space analysis can be predicted be performed with initial conditions.
2. The variables used to represent the system can be any variables in the system.
3. Using this analysis the internal states of the system at any time instant.

9. **What is meant by sampled data control system? /Digital Control system/Discrete control System(Nov 2012)**

When the signal or information at any or some points in a system is in the form of discrete pulses, then the system is called discrete data system or sampled data system.

10. **What is meant by quantization? (May 2011, May 2012)**

The process of converting a discrete-time continuous valued signal into a discrete-time discrete valued signal is called quantization. In quantization the value of each signal sample is represented by a value selected from a finite set of possible values called quantization levels.

11. **Explain the term sampling and sampler?**

Sampling is a process in which the continuous time signal is converted into a discrete time signal by taking samples of the continuous time signal at discrete time instants. Sampler is a device which performs the process of sampling.

12. **Differentiate between digital and Analog controllers.**

S.No.	**Analog controller**	**Digital controller**
1.	Analog system uses continuous signals.	Digital system uses discrete signals.
2.	Analog Controller is complex	Digital Controller is Simple.
3.	It is non programmable.	It is programmable.
4.	It is not flexible in nature.	It is flexible.
5.	It is costlier	It is less costlier

13. **State Shannon's sampling theorem.(May 2015, Nov 2016, May Nov 2017, May 2018)**

It 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.

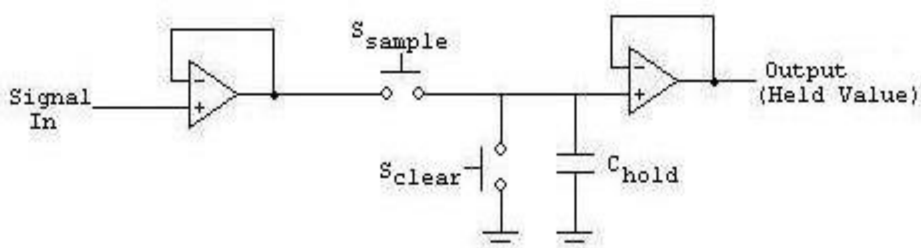
14. **What are the advantages of state space modelling using physical variables?**

a) Can perform both Time variant and time invariant systems as well

b) can be applied to MIMO System

c) Sate space modelling can be applied for Nonlinear systems

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

15.	**When the control system is called sampled data system?** a) When a digital computer or microprocessor or digital device is employed as a part of the control loop. b) When the control components are used on time sharing basis. c) When the control signals are transmitted by pulse modulation.(Move to top)
16.	**What are phase variables?** The phase variables are defined as those particular state variables which are obtained from one of the system variables and its derivatives. Usually the variables used are the system output and the remaining state variables are then derivatives of the output.
17.	**Write the canonical form of state model for n^{th} order system. (NOV 2019)** For a general n^{th} order transfer function: $$H(s) = \frac{Y(s)}{U(s)} = \frac{b_0 s^n + b_1 s^{n-1} + \cdots + b_{n-1} s + b_n}{s^n + a_1 s^{n-1} + \cdots + a_{n-1} s + a_n}$$ The observable canonical state space model form is
	$$a = Aq + Bu; \quad A=\begin{bmatrix} -a_1 & 1 & 0 & .. & 0 \\ -a_2 & 0 & 1 & 0 & : \\ : & : & 0 & .. & 0 \\ -a_{n-1} & 0 & : & .. & 1 \\ -a_n & 0 & 0 & .. & 0 \end{bmatrix}; \quad B=\begin{bmatrix} b_1 - a_1 b_0 \\ b_2 - a_2 b_0 \\ : \\ b_{n-1} - a_{n-1} b_0 \\ b_n - a_n b_0 \end{bmatrix}$$
18.	**What are the different methods available for computing Sate Transition matrix (e^{At}) ?** a) Using matrix exponential b) Using Laplace transform c) Using canonical transformation d) Using Cayley-Hamilton theorem
19.	**Draw the circuit diagram of sample and hold circuit. (May 2014, Nov 2015)** 

20.	**Write the properties of state transition matrix. (May 2010, May 2014, Nov 2016)** The following are the properties of state transition matrix. 1. $\phi(0) = e^{A\times 0} = I\,(unit\,matrix)$ 2. $\phi(t) = e^{At} = \left(e^{-At}\right)^{-1} = \left[\phi(-t)\right]^{-1}$ 3. $\phi(t_1 + t_2) = e^{A(t_1+t_2)} = e^{At_1}\,e^{At_2} = \phi(t_1)\phi(t_2) = \phi(t_2)\phi(t_1)$
21.	**What is resolvant matrix?** The Laplace transform of state transition matrix is called resolvant matrix. Resolvant matrix, $\phi(s = L\,[\phi(t)] = \mathrm{L}\,[e^{At}]$ and *Also*, $\phi(s) = [sI\text{-}A]^{-1}$
22.	**What are the different methods available for computing e^{At}?** The following four methods are available for computing.e^{At} 1. Computation of e^{At}using Laplace transform. 2. Computation of e^{At} using matrix exponential. 3. Computation of e^{At} using canonical transform. Computation of e^{At} using Cayley-Hamilton Theorem.
23.	**Write the advantages and disadvantages of sampled data control system?(May 2017)** **Advantages:** a) Systems are highly accurate, fast and flexible. b) Digital transducers used in the system have better resolution c) The digital components are less affected by noise, non-linearites. **Disadvantages:** a) Conversation of analog signals to discrete time signals and reconstruction introduce noise and errors in the signal. b) Additional filters have to be introduced in the system if the component of the system does not have adequate filtering characteristics