EC3351 CONTROL SYSTEMS-QUESTION BANK

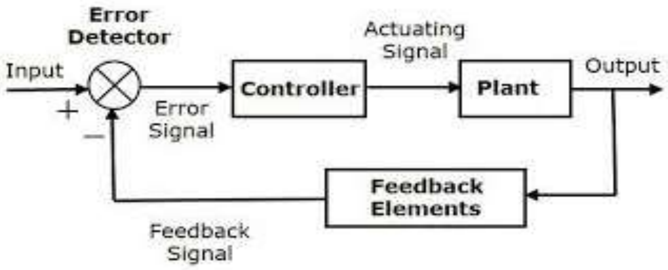
UNIT I – SYSTEMS COMPONENTS AND THEIR REPRESENTATIONS

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 advantages and disadvantages of open loop control systems?**

Advantages/Merits

- Open loop control is much simpler and less expensive
- No sensors are needed to measure the variable
- Stable system
- Maintenance is easy

	• Simple in design and construction Disadvantages/Demerits • Not accurate • There is no compensation for any disturbances entering the system • Unreliable • Any change in input does not affect the output/ desired specification cannot be obtained
5.	**What are the advantages and disadvantages of closed loop control systems?(May, Nov 2012,May 2017)** Advantages/Merits • More accurate • It compensates for disturbances • It greatly improves the speed of its response • Less effective to noises which might give the system robustness • Automatic system can be performed. Disadvantages/Demerits • More complex and expensive • Reduces the gain of the system • If the closed loop system is not properly designed, the feedback may lead to instability. • Feedback might cause oscillatory behavior
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 (ii) Positive feedback system where output and set point values are added used in oscillators
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 • 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.

$$\text{transfer function} = \left.\frac{\text{laplace transform of the output}}{\text{laplace transform of the input}}\right|_{\text{Zero initial conditions}}$$

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 $\alpha_1X_1(t)+ \alpha_2X_2(t)$ is given by the linear combination of the individual outputs, i.e.,$\alpha_1Y_1(t)+ \alpha_2 Y_2(t)$ where $\alpha1$, $\alpha2$ 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.	**What are analogous systems?** The systems for which the differential equations in physical systems have similar forms are known as analogous systems, for example electrical systems equivalent to mechanical systems. There exists a fixed analogy between Electrical and Mechanical systems which is similar under the Equilibrium conditions
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).
21.	**Define resistance and capacitance of liquid level system. (Nov2013)** **Resistance:** It is defined as the change in the level difference necessary to cause the unit change in flow rate. **Capacitance:** it is defined as the change in quantity of stored liquid necessary to cause a unit change in head (height).
22.	**Write the analogous elements in torque voltage analogy for the elements of mechanical rotational system. (May 2018).**

Mechanical system components	**Equivalent Electrical Element**	
	Force - Voltage analogous	***Force - Current analogous***
Mass	Inductance (L)	Capacitance (C)
Damper	Resistance (R)	Reciprocal of resistance (1/R)
Spring	Reciprocal of capacitance (1/C)	Reciprocal of inductance (1/L)

23.	**What is servomechanism?** The servomechanism is a feedback control system in which the output is mechanical position. Servomechanism is a powered mechanism in which the output motion or force is considerably higher than the input energy. Servomechanism is particularly used to make the control automatic system. The servomechanism is a feedback control system in which the output is mechanical Position (or) time derivatives of position (e.g. velocity & acceleration).
24.	**What is electrical analogous of a gear?** Transformer is electrical analogous of a gear. Transformer has N_1 and N_2 has number of turns whereas Gears as L_1 and L_2 as the level. N_1 and N_2 can be step up or step down approach. L_1 and L_2 can be the mechanical transitions for increasing the speed using gear teeth
25.	**Mention the equivalent electrical elements for the moment of Inertia - damper – torsional spring elements in mechanical system.(OR)** **Write the Force-Voltage analogous of a mechanical spring and dash pot.(Dec 2018)**

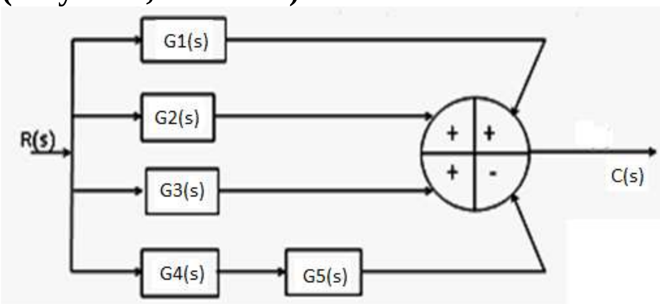
Mechanical system components	**Equivalent Electrical Element**	
	Force - Voltage analogous	***Force - Current analogous***
Moment of Inertia J	Inductance (L)	Capacitance (C)

Rotational frictional coefficient of dashpot B	Resistance (R)	Reciprocal of resistance (1/R)
Stiffness of Spring K	Reciprocal of capacitance (1/C)	Reciprocal of inductance (1/L)

26\. **What is meant by 'block diagram of a control system? What are the basic components of a block diagram? (Nov 2011)**

A block diagram of a system is a pictorial representation of the functions performed by each component of the system. The basic elements of block diagram are Block, Branch point and Summing point.

27\. **Write down the transfer function of the system whose block diagram is shown below. (May 2011, Nov 2012)**



When the gains are in series the net gain is its product. In the above figure the gains G4(s) and G5(s) are in series and their gain product is G4(s)*G5(s).The gain product is in parallel with the other branches.

Therefore

$$\frac{C(s)}{R(s)} = G_1(s) + G_2(s) + G_3(s) - G_4(s)G_5(s)$$

28\. **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

29\. **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

30\. **State Mason's Gain formula. (May 2013, May 2014, Dec 2014, May & Nov 2015 May 2016, May 2017)**

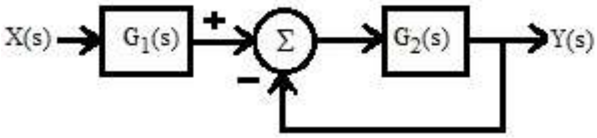
Mason's gain formula is given by,

$$T = \frac{1}{\Delta}\sum_k P_k \Delta_k$$

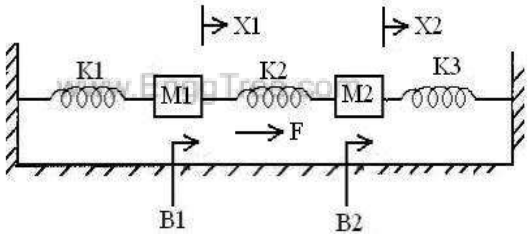
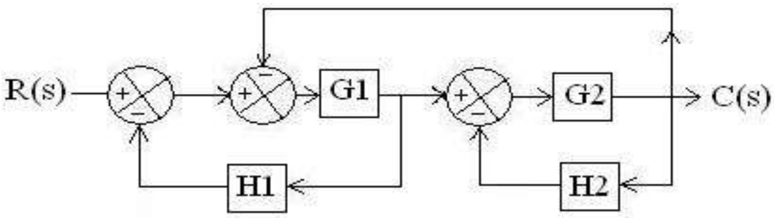
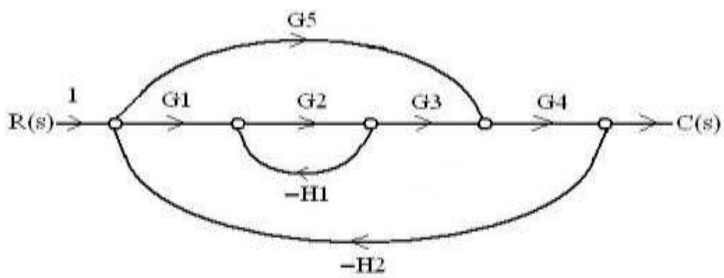
P_k = path gain of k^{th} forward path.

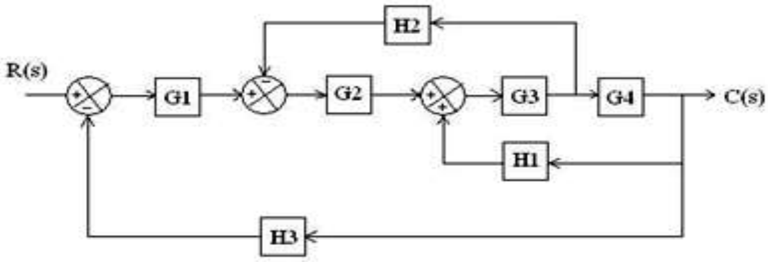
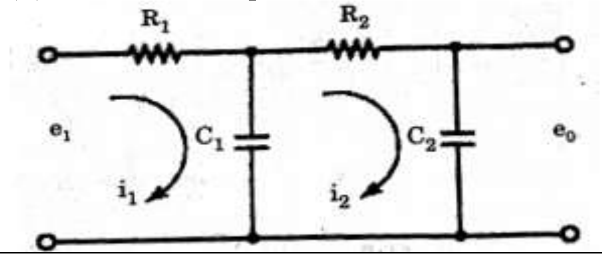
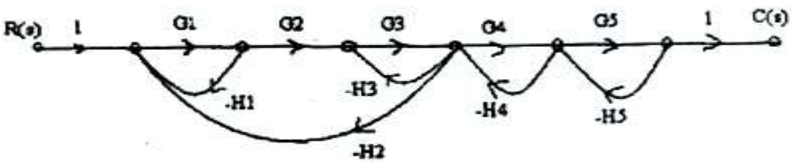
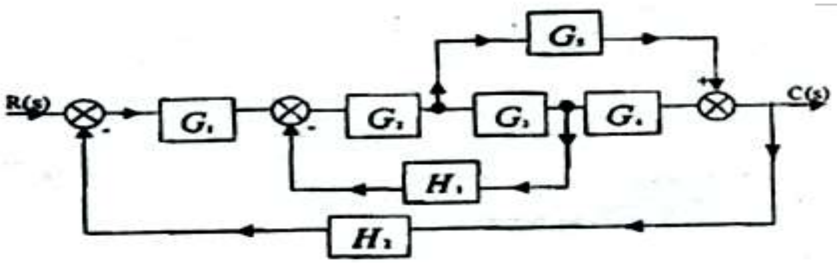
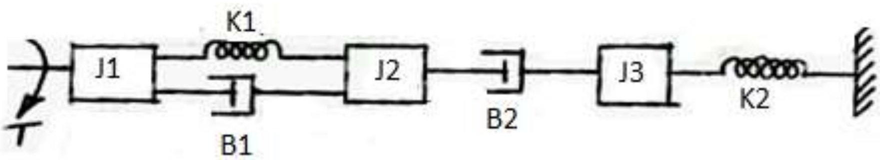
Δ = 1- (sum of individual loop gains) + (sum of gain of all combinations of two non-touching loops) – (sum of gain product of all combinations of three non-touching loops)

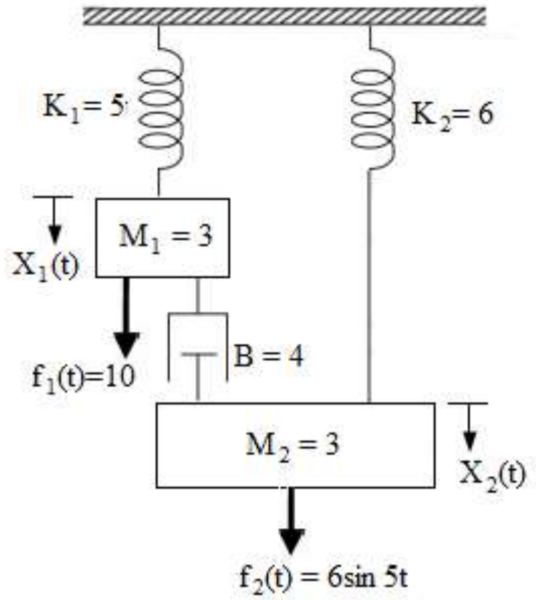
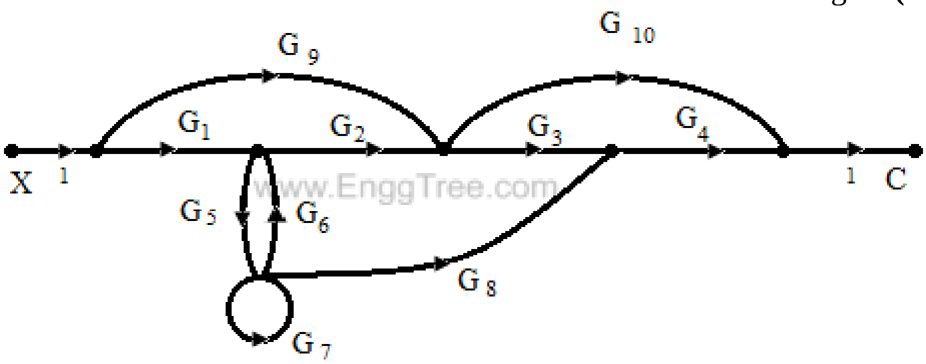
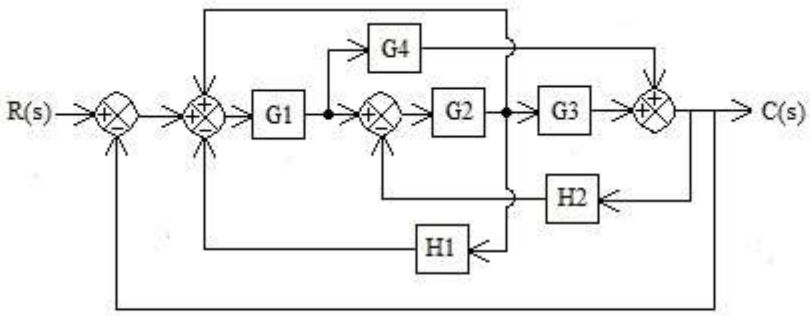
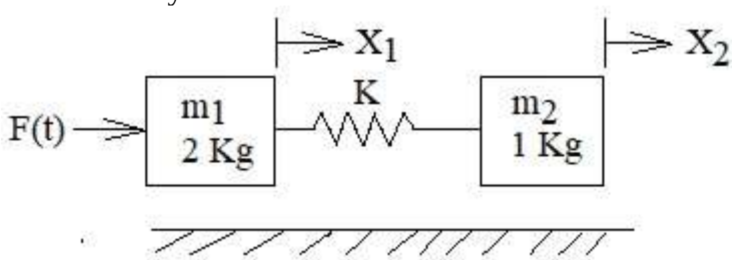
Δ_k = Δ of that part of graph not touching the k^{th} forward path

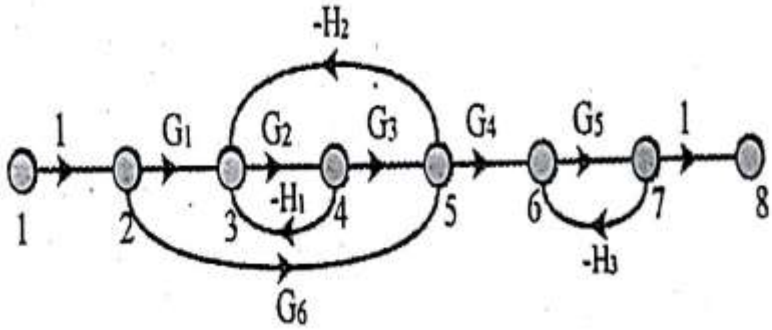
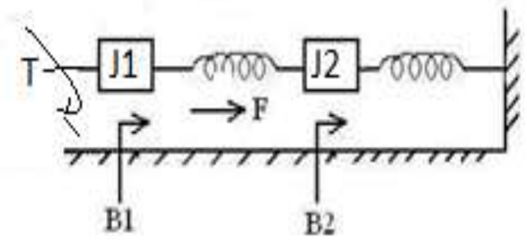
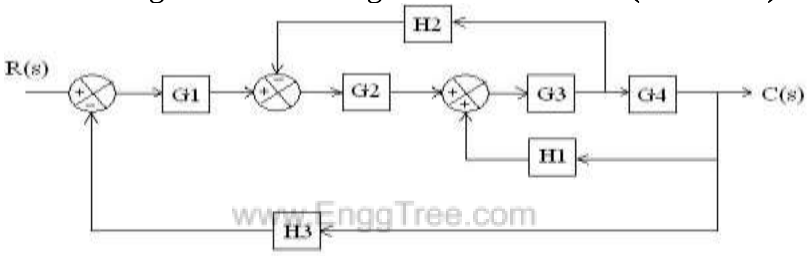
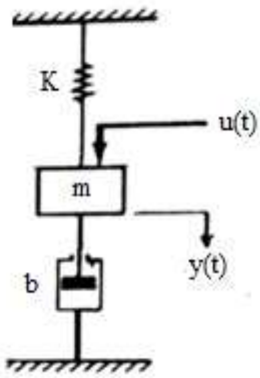
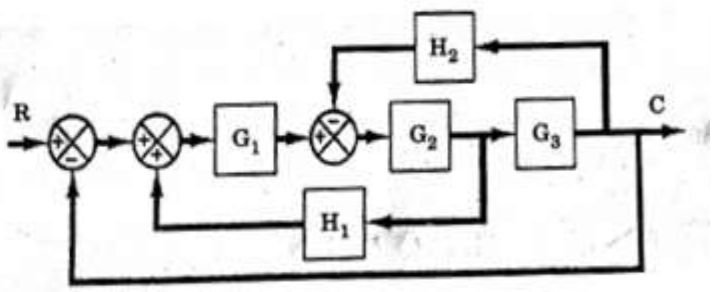
31.	**Find the transfer function of the network given in Fig. 1(May 2015, Nov 2017)**  The unity feedback loop is reduced to $\frac{G_2(s)}{1+G_2(s)}$ .It is in series with $G_1(s)$.Therefore the Transfer function $\frac{Y(s)}{X(s)}=\frac{G_1(s)G_2(s)}{1+G_2(s)}$
32.	**Specify the usefulness of AC servomotors in motion control systems. (NOV 2019)** AC servomotors can be controlled at very low speed and sometimes even at the zero speed. The servo motor is widely used in radar and computers, robot, machine tool, tracking and guidance systems, processing controlling.
33.	**What is a Multivariable control system?** In a control system if we have many manipulated control variables then the system is called as multivariable control system. Example is in a boiler where both the temperature and level has to be controlled.

PART B

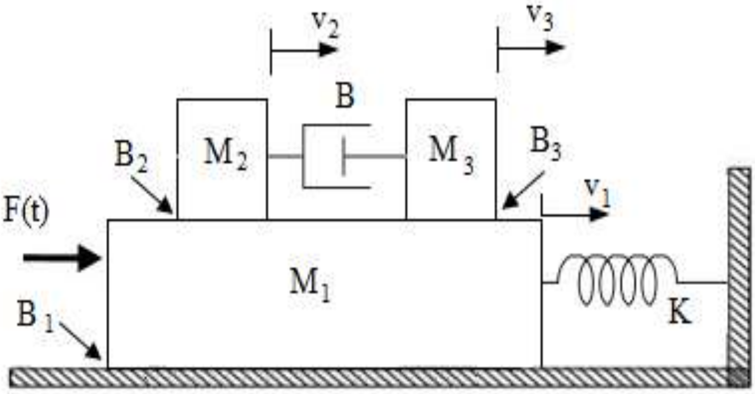
1.	Draw the equivalent mechanical system of the system shown in fig. Write the set of equilibrium equations for it and obtain electrical analogous circuits using (i) F-V analogy (ii) F-I analogy. 
2.	i) Reduce the block diagram shown in fig and obtain its closed loop transfer function $\frac{C(s)}{R(s)}$  ii) Find $\frac{C(s)}{R(s)}$ by using Mason's gain formula for the signal flow graph shown. 
3.	i) Determine the transfer function for the system having the block diagram as shown in figure. **(Nov 2016)**

	 ii) Determine the transfer function of the network shown below. Write the differential equations governing the electrical system as shown in figure and determine the transfer function $E_o(S)/E_1(S)$. Assume the capacitance C_1 and C_2 are not charged initially. 
4.	i) Find $\frac{C(s)}{R(s)}$ for the signal flow graph shown below. 
5.	Derive the transfer function of a RLC series circuit.
6.	With a neat diagram, derive the transfer function of a field controlled dc motor.
7.	i) Derive the expression for the Transfer function of Armature controlled DC motor. ii)Draw the signal flow graph for the following system and obtain the Transfer function using Mason gain formula $x_2 = a_{12}x_1 + a_{22}x_2 + a_{32}x_3$ $x_3 = a_{23}x_2 + a_{43}x_4$ $x_4 = a_{24}x_2 + a_{34}x_3 + a_{44}x_4$ $x_5 = a_{25}x_2 + a_{45}x_4$
8.	i) Reduce the block diagram to its canonical form and obtain $\frac{C(s)}{R(s)}$. (10) ii) Give the comparison between block diagram and signal flow graph methods. 
9.	Write the differential equation governing the mechanical rotational system shown in figure below. 

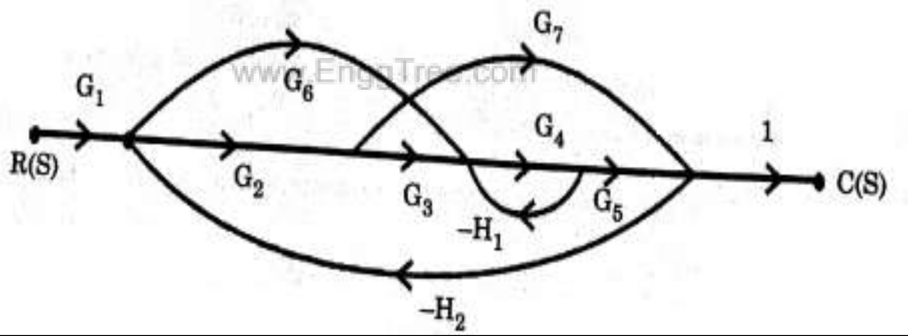
	Draw the torque-voltage and torque current electrical analogous circuits and verify by writing mesh and node equations.
10.	Write the differential equations governing the behavior of the translational mechanical system shown in figure1. 
11.	State Mason's Gain formula and use Mason's Gain formula to find overall gain.**(Dec 2018)** 
12.	Use Mason's Gain formula to obtain $C(s)/R(s)$ of the system shown below. 
13.	i) Explain the features of closed loop feedback control system. ii) Derive the transfer function of system. 
14.	i) The signal flow graph for a feedback control system is shown in figure. Determine the closed loop transfer function. C(S)/R(S).

	 ii) State any four block diagram reduction rules
15.	Write the differential equations governing the mechanical rotational system shown in figure. Draw the electrical equivalent analogy circuits (current and voltage) **(Nov 2016)** 
16.	i)Reduce the block diagram shown in figure and find C/ R. **(Nov 2016)**  ii) Compare open loop and closed loop control system.
17.	Draw the equivalent electrical analogous circuit for the mechanical System shown below force voltage analogy **(May 2017).** 
18.	Simplify the following diagram using block diagram reduction method. Also derive the transfer function of the same using signal flow graph. **(May 2017)** 

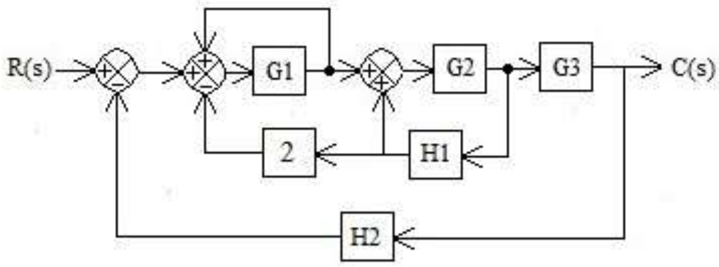
19. Write the differential equation governing the mechanical system shown in figure and determine the transfer function $V_1(S)/F(S)$. **(Nov 2017)**



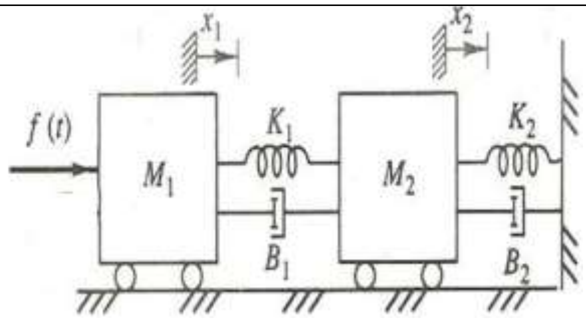
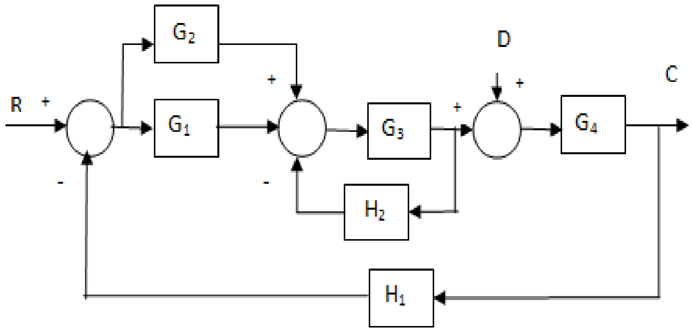
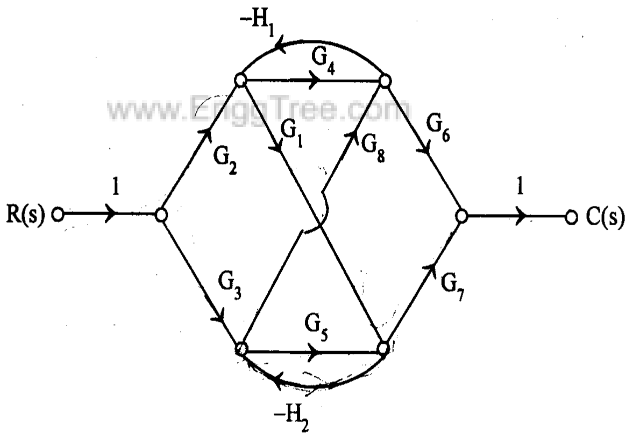
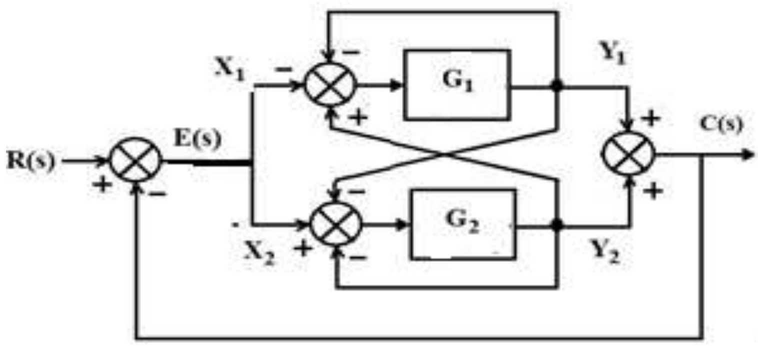
20. Obtain the closed loop transfer function of the system, by using Mason's gain formula. (**Nov 2017, May 2018).**

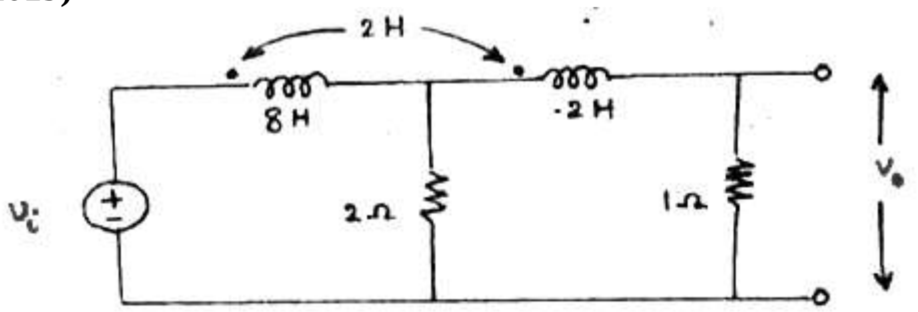
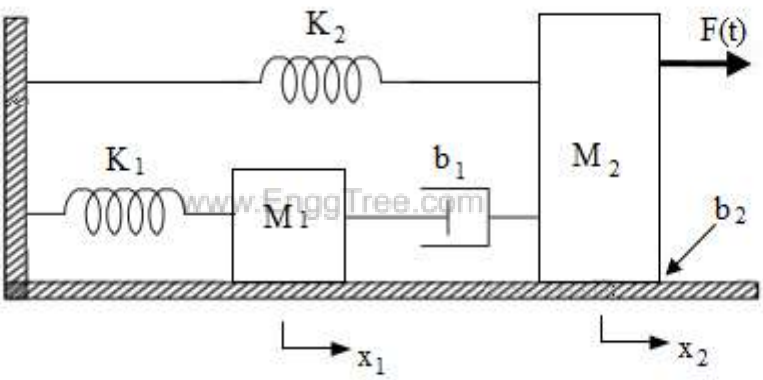
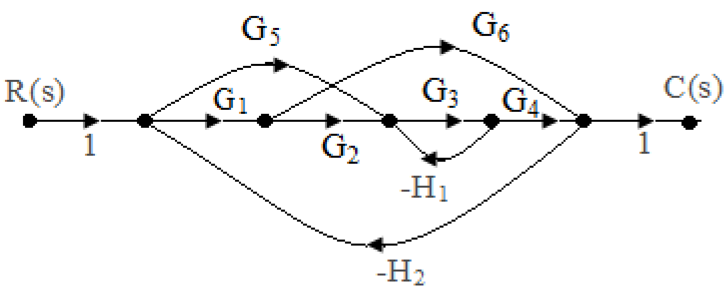


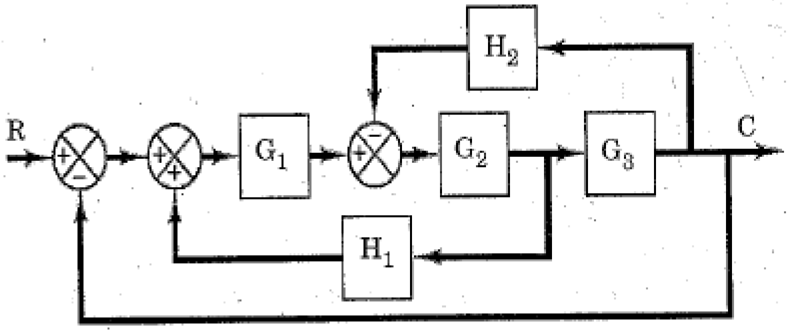
21. Find the transfer function of the system in Fig.3 using block diagram reduction technique and signal flow graph technique. **(May 2015)**



22. Write the differential equations governing the mechanical translational system as shown in figure. Draw the Force – Voltage and Force –Current electrical analogous circuits and verify by mesh and node equations.

	
23.	i) Determine the ratio C/R and C/D. Also find the total output for the system whose block diagram is shown in figure.  ii) Using Mason's gain formula find $C(s)/R(s)$ for the signal flow graph shown in figure. 
25.	i) Using block diagram reduction technique, find the closed loop transfer function C/R of the system whose block diagram is shown below.**(Dec 2018)**  ii) Construct the signal flow graph for the following set of simultaneous equations and obtain the overall transfer function using Mason's gain formula.

	$X_2 = A_{21}X_1 + A_{23}X_3$ $X_3 = A_{31}X_1 + A_{32}X_2 + A_{33}X_3$ $X_4 = A_{42}X_2 + A_{43}X_3$
24.	Obtain the transfer function for the coupled circuit as shown Fig. 1 **(MAY 2019)**  Fig. 1
25.	Write the differential equations governing the motion of the mechanical system as shown in Fig. Also obtain its' analogous electrical circuit using either force-voltage or force-current analogy.**(MAY 2019)** 
26.	Convert the signal flow graph shown in fig. to block diagram representation and thereafter obtain the overall transfer function of the system by block diagram reduction technique. **(May 2019)** 
27.	Describe the construction and working principle of synchro's. Also explain how it is used in servo applications.**(NOV 2019)**
28.	Draw the signal flow graph for the given system block diagram and obtain the closed loop transfer of the system C(S)/R(s) using Manson's Gain formula. (**NOV 2019)**

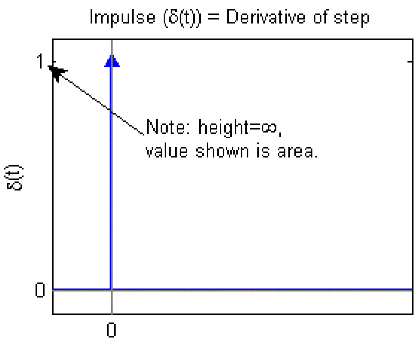
UNIT II- TIME RESPONSE ANALYSIS

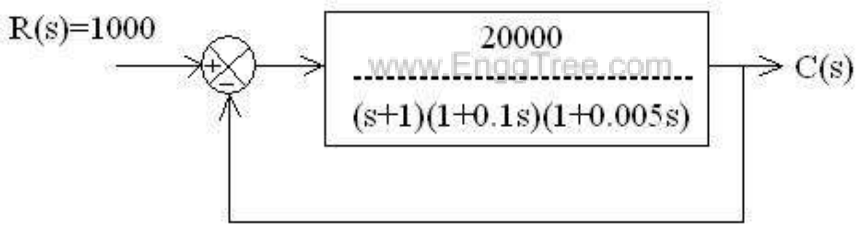
Transient response-steady state response-Measures of performance of the standard first order and second order system-effect on an additional zero and an additional pole-steady error constant and system- type number-PID control-Analytical design for PD, PI,PID control systems

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.	**Define a impulse function.** A signal which has infinite magnitude at time equal to zero only. We can assume it as a lightning pulse which acts for a short duration with infinite magnitude of voltage. 

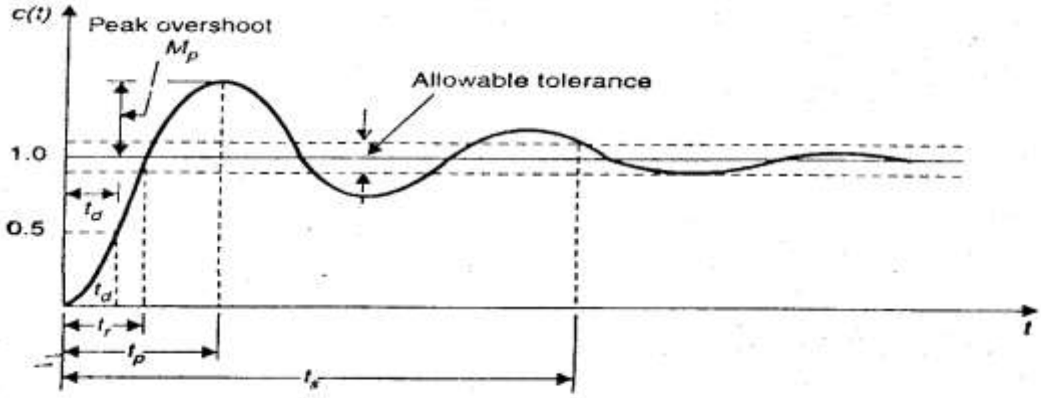
6.	**For the system with the following transfer function, determine type and order of the system. (Nov 2009)** **i)** $G(s)H(s)=\frac{(s+4)}{(s-2)(s+0.25)}$ **ii)** $G(s)H(s)=\frac{200}{s(s^2+20s+200)}$ **Type of a system:** Type no is given by number of poles of loop transfer function at origin of S-plane. **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 $t_r=\frac{\pi-\theta}{\omega_d}=\frac{\pi-\tan^{-1}\frac{\sqrt{1-\xi^2}}{\xi}}{\omega_n\sqrt{1-\xi^2}}$ 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= $t_p=\frac{\pi}{\omega_n\sqrt{1-\xi^2}}$ 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 settling time.** Settling time is defined as the time taken by the response to reach and stay within the specified tolerance band (error). It is usually expressed as % of final value. The usual tolerance band is ±2% or ±5% of the final value. $t_s = \frac{4}{\xi\omega_n} = 4T$, for ±2% tolerance band $t_s = \frac{3}{\xi\omega_n} = 3T$, for ±5% tolerance band Where ω_n is the natural frequency; ξ is the damping ratio;
15.	**Define maximum peak overshoot.** Maximum Peak overshoot is defined as the ratio of maximum value measured from the steady 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(α)is the output at infinity time.
16.	**Define damping ratio.** Damping ratio is defined as the ratio of actual damping to critical damping Damping ratio= $\xi = \frac{\text{Actual damping}}{\text{Critical damping}}$
17.	**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, $\xi > 1$
18.	**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
19.	**Give the steady state errors to a various standard inputs for type-2 system.(May 2013)** **Input signal** — **SteadyState error** Step input — 0 Ramp input — 0 Parabolic input — 1/Ka
20.	**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 $\frac{1}{1 + Kp}$
21.	**Steady state error will be zero if the system has a PI controller. State true or false.** True. The integral controller eliminates the steady state error. the advantage of PI controller, that it minimizes the steady state error so that output tries to follow reference input
22.	**Define velocity error constant.**

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

The steady state error in type – 1 system for unit ramp input is given by $\frac{1}{K_v}$

23. **Sketch the response of second order underdamped system./ Draw the unit step response curve for the second order system and show the time domain specifications.(May 2018)**



In the above graph
M_p is the peak overshoot;t_r is the rise time;t_p is the peak time;t_d is the delay time;
t_s is the settling time;C(t) is the response.

24. **The closed loop transfer function of a second order system is given by $\frac{400}{s^2+2s+400}$. Determine the damping ratio and natural frequency. (May 2013)**

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2} = \frac{400}{s^2+2s+400}$$

$$\omega_n^2 = 400$$

$$\omega_n = \sqrt{400} = 20 \ rad/\sec$$

$$2\xi\omega_n = 2$$

$$\xi = \frac{2}{2\omega_n} = \frac{1}{20} = 0.05$$

Since ξ<1, the system is underdamped

25. **Define acceleration error constant.**

The acceleration error constant $K_a = \lim_{s\to 0} s^2\,G(s)H(s)$. Here G(s)H(s) is the loop transfer function.

The steady state error in type – 2 system for unit parabolic input is given by $\frac{1}{Ka}$

26. **Enumerate the advantages of generalized error coefficients.**

- Generalized error co-efficient gives the steady state error as the function of time.
- Using generalized error co-efficient the steady state can be found for any type of input, but static error constants are used to determine steady state error when the input is anyone of standard input.

27. **What is the effect on system performance when a proportional controller is introduced in a system?**

The proportional controller improves the steady state tracking accuracy, disturbance signal rejection and relative stability of the system. It also increases the loop gain of the system which results in reducing the sensitivity of the system to parameter variations.

28. **Distinguish between generalized error constants over static error constants.**

S.No	**Static error constants**	**Generalized error constants**

		1	Static error constants do not give the information regarding the variation of error with time.	Generalized error constants gives error signal as a function of time.
		2	Static error constants can be used only for standard inputs.	Using generalized error constants the steady state error can be determined for any type of input.
		3	They give the definite values for errors, either 0 or ∞ a finite value.	They give the exact error values.
29.	**What are the types of controllers that are used in a closed loop system?** • Proportional controller • Integral controller • Proportional + Integral • Proportional + derivative • Proportional + Integral + Derivative			
30.	**What is meant by reset time?** In the integral mode of controller, the time during which the error signal is integrated is called the integral or reset time (T_i). In other words, the time taken by the PI controller to 'reset' the set point to bring the output to the desired value, $U(s)=Kc\left(1+\frac{1}{T_i s}\right)\times E(s)$ where Ti is the integral (or) reset time;E(s) is the error signal; Kc is the controller gain;			
31.	**What is a derivative controller? What is its effect?** Derivative controller is a device that produces a control signal, which is proportional to the rate of change of input error signal. It is effective only during transient response and does not produce any corrective measures for constant errors. The main usage of the 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.			
32.	**Why derivative control action is never used alone?** Since the derivative controller's output is directly proportional to the rate of change of error signal 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			
33.	**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			
34.	**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			
35.	**Explain the function of a PID controller. (Nov 2003)** It combines all the three continuous controlling modes, gives the output which is proportional to the error signal, proportional to the rate of change of error signal and proportional to the integral of error signal. So it has all the advantages of three individual modes. i.e. less rise time, less oscillations, zero offset and less settling time.			
36.	**What is a proportional controller?**			

The proportional controller produces an output signal, which is proportional to the error signal. The controller output, u α e

$u = k_p e$.

37. **Find the unit impulse response of system**

$H(s) = \dfrac{5s}{s^2+4}$ **with zero initial conditions.**

$\dfrac{C(s)}{R(s)} = H(s) = \dfrac{5s}{(s^2+4)}$; R(s) = Unit impulse input = 1

$C(t) = L^{-1}\left[R(s)H(s)\right] = L^{-1}\left[\dfrac{5s}{(s^2+4)}\right] = 5\cos 2t$

38. **Find the unit impulse response of system** $H(s) = \dfrac{5s}{s+2}$ **with zero initial conditions.(May 2015)**

$\dfrac{C(s)}{R(s)} = H(s) = \dfrac{5s}{(s+2)} = \dfrac{5s+10-10}{(s+2)}$

$= \dfrac{5(s+2)-10}{(s+2)} = 5 - \dfrac{10}{(s+2)}$; R(s) = Unit impulse input = 1

$C(t) = L^{-1}\left[R(s)H(s)\right] = L^{-1}\left[5 - \dfrac{10}{(s+2)}\right] = 5\delta(t) - 10e^{-2t}$

39. **Write the mathematical expressions for step input and impulse input.(Nov 2016)**

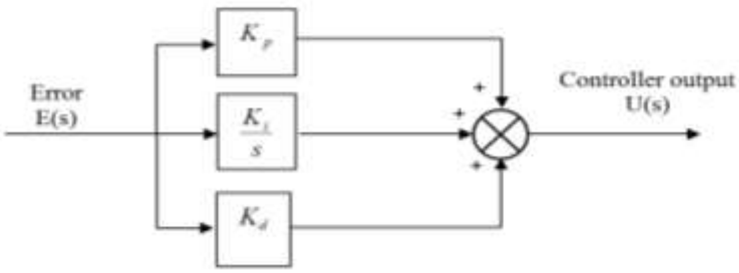
Unit Step input :$U(t) = \begin{cases} 0, & t < 0 \\ 1, & t \geq 0 \end{cases}$

Unit impulse input : δ(t) = 1 ; when t =0

40. **Define steady state error (Nov 2016, May 2017)**

Steady-state error is defined as the difference between the input (command) and the output of a system in the limit as time goes to infinity. (i.e value of error when time goes to infinity)

41. **Draw transfer function model for PID Control (May 2017)**



Transfer function of PID controller $\dfrac{U(s)}{E(s)} = \left(K_p\left(1 + \dfrac{K_i}{s} + K_d s\right)\right)$

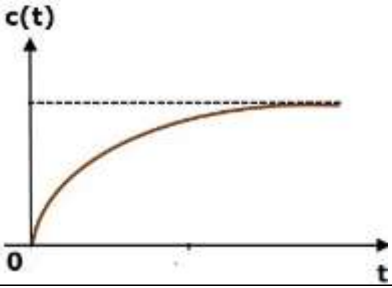
Where K_p is the proportional gain; K_i is the integral gain; K_d is the derivative gain; E(s) is the error signal; U(s) is the controller output;

42. **What are the generalized Error Coefficients?/ What are the dynamic error coefficients? (Nov 2017, May 2018)**

Input	Steady-State error formula	Type 0		Type 1		Type 2	
		Static error constant	Error	Static error constant	Error	Static error constant	Error
Step *u(t)*	$\dfrac{1}{1+K_p}$	K_p = constant	$\dfrac{1}{1+K_p}$	$K_p = \infty$	0	$K_p = \infty$	0

Ramp ***tu(t)***	$\frac{1}{K_v}$	$K_v = 0$	∞	K_v =Constant	$\frac{1}{K_v}$	$K_v = \infty$	0
Parabola $\frac{1}{2}t^2u(t)$	$\frac{1}{K_a}$	$K_a = 0$	∞	$K_a = 0$	∞	K_a =Constant	$\frac{1}{K_a}$

43. **What will be the response of a first order system with Unit step input.(May 2018)**



44. **For the given transfer function, find the type and order of the system. (NOV 2019)**

$$\frac{C(S)}{R(S)} = \frac{10(s+2)}{s(s^2+3s+5)}$$

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.
Type =1, Order=3

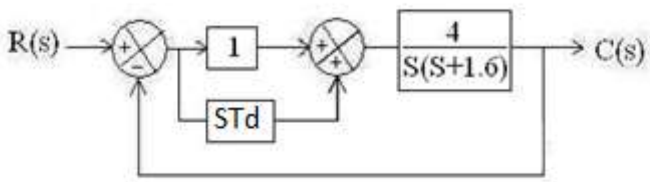
45. **Write a Transfer Function of a PID Controller. (May 2019)**

Transfer Function of PID Controller $U(s)/E(s) = K_p\,(1 + \frac{1}{T_i s + T_d s})$

Where K_p – Positional Error Constant
K_i – Integral Time Constant
K_d – Derivative Time Constant

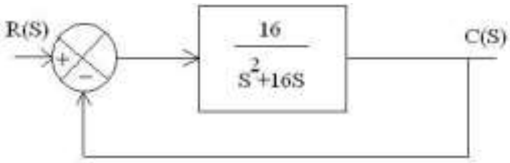
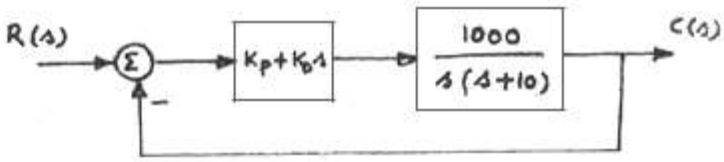
PART B

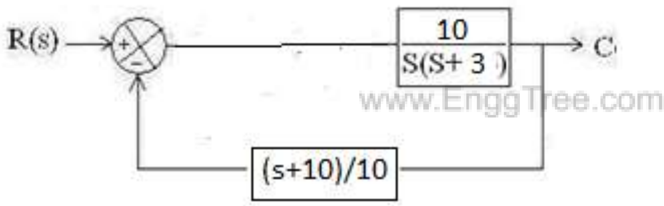
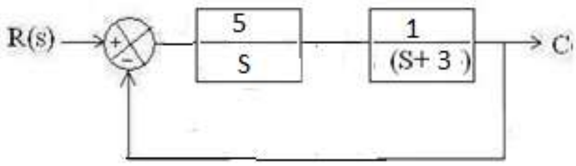
1. (i) Discuss the effect on the performance of a second order control system of the proportional derivative control.
(ii) Figure shows PD controller used
for the system. Determine the value of Td so that system will be critically damped. Calculate it's settling time.

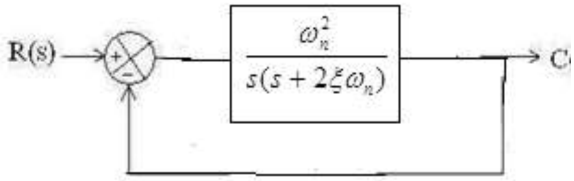


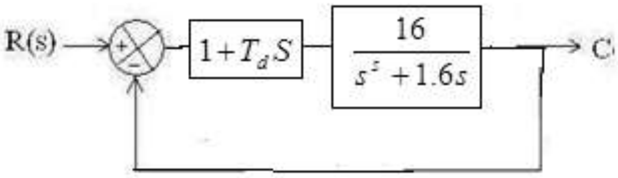
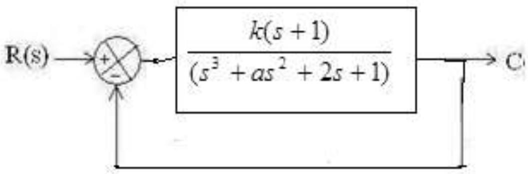
2. Derive the expression of the step response of a standard second order underdamped system. Use standard notations.**(May 2019)**

3. i)A unity feedback system has $G(s) = \frac{40(s+2)}{s(s+1)(s+4)}$. Determine type of the system, all the error coefficients and error for ramp input with magnitude 4.

	ii) A second order system is given by $\frac{C(s)}{R(s)} = \frac{25}{s^2+6s+25}$. Find its rise time, peak time, peak over shoot and settling time if subjected unit step input. Also calculate expression for its output response.**(May 2009)**
4.	A unity feedback control system has an open loop transfer function $G(s) = \frac{10}{s(s+2)}$. Determine its closed loop transfer function, damping ratio and natural frequency of oscillations. Also evaluate the rise time, percentage overshoot, peak time and settling time for a step input of 12 units.**(May 2018)**
5.	An unity feedback control system is shown in fig. below. By using derivative control the damping ratio is to be made to 0.8. Determine the value of Td and compare rise time, peak time and maximum overshoot of the system. The input to the system being unit step. **(May 2010)** i) Without derivative control ii) With derivative control 
6.	i)The unity feedback system is characterized by an open loop transfer function $G(s) = \frac{K}{s(s+10)}$ Determine the gain K, so that the system will have damping ratio of 0.5. For this value of K, determine settling time, peak over shoot and time to peak overshoot for a unit step input. ii) A unity feedback system has the forward transfer function $G(s) = \frac{K_1(2s+1)}{s(5s+1)(1+s)^2}$. The input is applied to the system. Determine the minimum value of K1, if the steady state error is to be less than 0.1. **(May 2011, Nov 2012)**
7.	A unity feedback system with a PD controller as shown in Fig. Determine the values of K_P and K_D so that the steady state error to a unit ramp input is 0.001 and damping ratio is 0.5. 
8.	A unity feedback control system has an open loop transfer function G(s) = 10/s(s+5). Determine its closed loop transfer function, damping ratio and natural frequency of oscillations. Also evaluate the rise time, peak Overshoot, peak time and settling time for a step input of 12 units.**(NOV 2019)**
9.	Derive an expression for unit step response of a second order control system. **(Nov 2015)**
10.	With suitable block diagrams and equations, explain the following types of controllers employed in controls systems: **(May 2011, Nov 2012, Nov 2015)** 1. Proportional controller, 2.Proportional plus Integral controller, 3.PID controller and 4.Integral controller
11.	With a neat block diagram and derivation explain how PI, PD and PID compensation will improve the time response of system. **(May 2016)**

12.	A unity feedback system is characterised by the open loop transfer function $G(s)=\frac{1}{s(0.5s+1)(0.2s+1)}$. Determine the steady state errors for Unit step, Unit ramp and Unit acceleration unit. Also determine the damping ratio and natural frequency of the dominant roots. (**Nov2013**)
13.	Consider a unity feedback system with open loop transfer function $G(s)=\frac{75}{(s+1)(s+3)(s+8)}$. Design a PID controller to satisfy the following specifications. (i) The steady state error for unit ramp input should be less than 0.08. (ii) Damping ratio = 0.8 and (iii) Natural frequency of oscillations = 2.5 rad/sec. **(Nov 2011)**
14.	i) The open loop transfer function of a unity feedback control system is given by $G(s)=\frac{K}{s(sT+1)}$ where K and T are constants. By what factor should the amplifier gain be reduced so that the peak overshoot of unit step response of the system is reduced from 75% to 25%. ii) A certain unity negative feedback control system has the following forward path transfer function $G(s)=\frac{K(s+2)}{s(s+5)(4s+1)}$. The input applied is $r(t)=1+3t$. Find the minimum value of K so that the steady state error is less than 1. **(May 2012)**
15.	i)Determine the unit step response of the control system shown in the following figure. (**May 2014**)  ii) The open loop transfer function of a unity feedback system is given by $G(s)=\frac{20}{s(s+1)}$. The input function is $r(t) = 2 + 3t + t^2$. Determine generalized error coefficient and steady state error.
16.	(i).The open loop transfer function of a unity feedback system is given by $g(s)=\frac{200}{s(s+8)}$. The input function is r(t)=2t**.** Determine steady state error. If it is desired to reduce the existing error by 5% find the new gain of the system**.(Dec 2018)** (ii). Explain in detail about PID controllers used in control systems.**(Dec 2018)**
17.	i) A unity feedback system has the forward transfer function. $G(s)=\frac{ks}{(1+s)^2}$ For the input r(t) = 1 + 5t, find the minimum value of K so that the steady state error is less than 0.1(Use final value theorem). ii) Briefly discuss about step response analysis of second order system. **(May 2015)**
18.	i) For the system shown in the below figure, find the effect of PD controller with T_d = 1/ 10 on peak overshoot and settling time when it is excited by unit step input. 

	ii) Discuss the effect of PID controller in the forward path of a system. / State and Explain the effects of P, PI and PID controllers on the system dynamics. **(May 2015, Nov 2017, May 2018)**
19.	The unity feedback system is characterized by an open loop transfer function G(s) = K / s(s+10) Determine the gain K, so that the system will have a damping ratio of 0.5 for this value of K. Determine settling time, peak overshoot and peak time for a unit step input. **(May 2017)**
20.	(i)Consider the system shown in figure, where damping ration is 0.6 and the natural undamped frequency is 5 rad/sec. Obtain the (1) Rise Time (2) Rise time (3)Peak overshoot (4) Settling time when the system is subjected to a unit step input.**(Dec 2018)**  (ii)Derive the time domain specifications of a second order system subjected to a step input. **(Nov 2016)(Dec 2018)**
21.	i) What are the various standard test signals? Draw the characteristic diagram and obtain the mathematical representation of all.**(Dec 2014)** ii) Calculate the following parameters for the system whose natural frequency of oscillations is 10 rad/sec and damping factor is 0.707. **(Dec 2014)** (1) Delay Time (2) Rise time (3)Peak overshoot (4) Settling time
22.	i)Determine the steady state errors for the following inputs 5u(t), 5tu(t), $5t^2u(t)$ to a system whose open loop transfer function is given by $G(s)=\frac{100(s+2)(s+6)}{s(s+3)(s+4)}$ ii) With its block diagram explain the concepts of PI and PD compensation. **(Dec 2014)**
23.	i)For a unity feedback control system, the open loop transfer function is $G(s)=\frac{10(s+2)}{s^2(s+1)}$ Find (1) the position, velocity . acceleration error constants, (2) the steady state error when $R(s)=\left(\frac{3}{s}\right)-\left(\frac{2}{s^2}\right)+\left(\frac{1}{s^3}\right)$ **(Nov 2016)** ii)State the effect of PI & PD compensation on the system performance. **(Nov 2016)**
24.	Explain about briefly the operation of P, PI, and PID control compensation using simple MATLAB programs. **(May 2017)**
25.	A unity feedback control systems is characterized by the following open loop transfer function $G(S)=\frac{4S+1}{S(S+6)}$. Determine its transient response for unit step input and sketch the response. Evaluate the maximum overshoot and the corresponding peak time. **(Nov 2017)**
26.	i) Derive the time response of a first order system for unit step input. ii) The unity feedback control system is characterized by an open loop transfer function $G(s)=\frac{K}{s(s+10)}$. Determine the gain K, so that the system will have damping ratio of 0.5 for this value of K. Determine the peak overshoot and peak time for a unit step input.
27.	Consider a unity feedback system with a closed loop transfer function $\frac{C(s)}{R(s)}=\frac{Ks+b}{s^2+as+b}$ Determine the open loop transfer function G(s) .Show that the steady state error with unity ramp input is given by $\frac{a-K}{b}$

28.	i)A unity feedback system is characterized by an open loop transfer function $G(s)=\frac{k}{s(s+10)}$. Determine the gain k so that the system will have a damping ratio of 0.5. For this value of k, determine peak overshoot and peak time for a unit step input. ii) The following diagram shows a unity feedback, system with derivative control. By using this derivative control the damping ratio is to be made 0.5. Determine the value of T_d. 
29.	i)Determine K to limit the error of a system for input $1+8t+\frac{18}{2}t^2$ to 0.8 having $G(s)H(s)=\frac{K}{s^2(s+1)(s+4)}$ ii) The forward path transfer function of a unity feedback control system is given by $G(s)=\frac{2}{s(s+3)}$. Obtain an expression for unit step response of the system. **(May 2010)**
30.	i) Derive an expression to find steady state error of a closed loop control system. ii) The closed loop transfer function of a second order system is given by $G(s)=\frac{100}{s^2+10s+100}$. Determine the damping ratio, natural frequency of oscillations, rise time, settling time and peak overshoot.
31.	Determine the positive values of K and a so that the system below oscillates at a frequency of 2 rad/sec.**(Dec 2018)** 
32.	What is the need for PID control for feedback control systems? Explain how it is designed for second order systems. **(NOV 2019)**

UNIT III – FREQUENCY RESPONSE AND SYSTEM ANALYSIS

Closed loop frequency response-Performance specification in frequency domain-Frequency response of standard second order system- Bode Plot - Polar Plot- Nyquist plots-Design of compensators using Bode plots-Cascade lead compensation-Cascade lag compensation-Cascade lag-lead compensation

PART - A

1.	**Define band width.** The bandwidth is the range of frequencies for which the system normalized gain is more than -3db. The frequency at which the gain is -3db is called cut-off frequency.
2.	**Define cut-off rate.** The slope of the log-magnitude curve near the cut-off frequency is called cut-off rate. The cut-off rate indicates the ability of the system to distinguish the signal from noise.
3.	**Define Gain Crossover Frequency.** The gain crossover frequency is the frequency at which the magnitude of open loop transfer function is unity(0 dB)
4.	**What are the advantages of frequency domain analysis of control systems?**

	• The absolute and relative stability of the closed loop system can be estimated from the knowledge of the open loop frequency response. • The practical testing of system can be easily carried with available sinusoidal signal generators and precise measurement equipment • The transfer function of the complicated functions can be determined experimentally by frequency response tests. • The design and parameter adjustments can be carried more easily. • The corrective measure for noise disturbance and parameter variation can be easily carried. • It can be extended to certain non - linear systems
5.	**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).
6.	**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.
7.	**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.
8.	**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 $\omega = \omega_{gc}$
9.	**Define phase cross over frequency.** The phase cross over frequency is the frequency at which the phase of open loop transfer function is -180°.
10.	**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

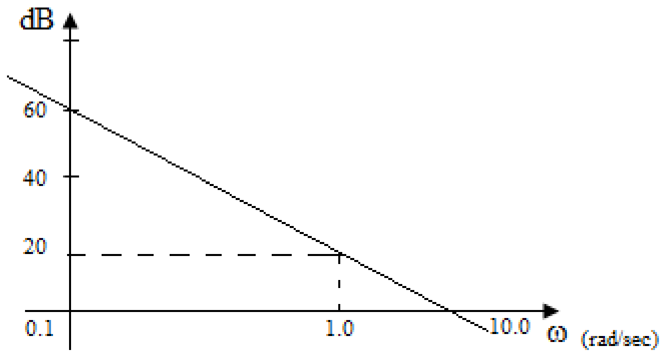
$$K_g \; in \, dB = 20\log(K_g) = 20\log\frac{1}{G(j\omega_{pc})}$$

11. **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.

12. **Obtain the transfer function of the system whose Bode magnitude plot given below: (May 2019)**



Transfer function $G(S)=\dfrac{100}{S^2(S+1)}$

13. **What is a minimum phase transfer function?**

A transfer function, which has all poles and zeros in the left half s – plane is known as minimum phase transfer function.

14. **In minimum phase system, how the starting and end point of polar plot are identified? (NOV 2019)**

Frequency (rad/sec)	Magnitude	Phase angle(degrees)
0	∞	-90 or 270
∞	0	-270 or 90

The polar plot starts at (∞,−90) and ends at (0,−270).

15. **Determine the frequency domain specification of a second order system when closed loop transfer function is given by $G(s)H(s)=\dfrac{64}{s^2+10s+64}$ (May 2010)**

$\omega_r = \omega_n\sqrt{1-2\varsigma^2}$

$\omega_n = 8$

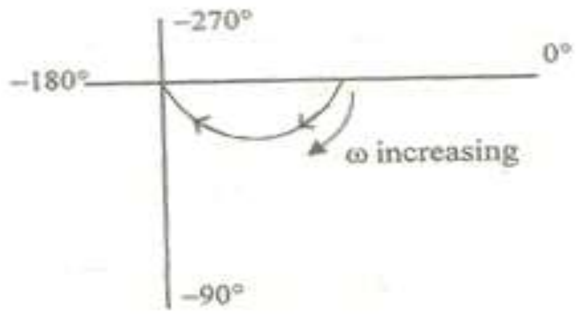
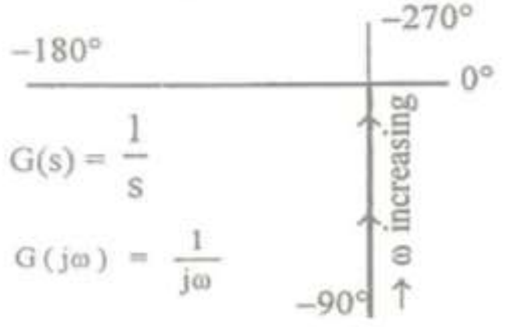
$\varsigma = 0.625$

16. **Derive the transfer function of a lead compensator network. (May 2010)**

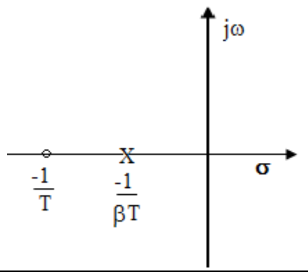
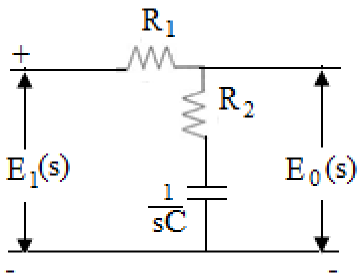
Transfer function of lead compensator, $G_C(s)=\dfrac{s+z_c}{s+P_c}=\dfrac{s+\frac{1}{T}}{s+\frac{1}{\alpha T}}$

The lead compensator has a pole at $S=-\frac{1}{\alpha T}$ and a zero at $S=-\frac{1}{T}$. Since $\alpha < 1$ and $T > 0$,the zero of lead compensator is nearer to origin.

17.	**The damping ratio and the undamped natural frequency of a second order system are 0.5 and 5 respectively. Calculate the Resonant frequency. (May 2014)** $\omega_r = \omega_n \sqrt{1-2\xi^2}$ The resonant frequency, $\omega_r = 5\sqrt{1-2(0.5)^2}$ $\omega_r = 3.5355$ Here ω_r is the resonant frequency; ω_n is the natural frequency; ξ is the damping ratio;
18.	**What are constant M and N circles? (Nov 2013, May 2016)** 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 is called M circles. Let N = tan a, Where a is the phase of closed loop transfer function with unity feedback. For each value of N, a circle can be drawn in the complex plane. The family of these circles is called N circles.
19.	**What is the use of constant M circles?** Constant M circles are used to find the closed loop frequency response graphically from the open loop frequency response G (jω) without calculating the magnitude and phase of the closed loop transfer function at each frequency
20.	**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.
21.	**Write the MATLAB statement to draw the Bode plot of the given system. (May 2013)** $\frac{Y(s)}{U(s)} = \frac{4s+6}{s^3+3s^2+8s+6}$ num=[4 6] den=[1 3 8 6] bode(tf(num,den))
22.	**Write the MATLAB command for $\frac{Y(s)}{U(s)} = \frac{4s+6}{s^3+3s^2+8s+6}$ plotting Bode diagram (Nov 2011)** num=[4 6] den=[1 3 8 6] sys=tf(num,den) bode(sys)
23.	**Draw the polar plot of $G(s) = \frac{1}{(1+sT)}$ (May 2012)**

	
24.	**Draw the polar plot of an integral term transfer function. (May 2013)** 
25.	**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.
26.	**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.
27.	**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.
28.	**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
29.	**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
30.	**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
31.	**Draw the circuit of lag compensator and draw its pole zero diagram.**

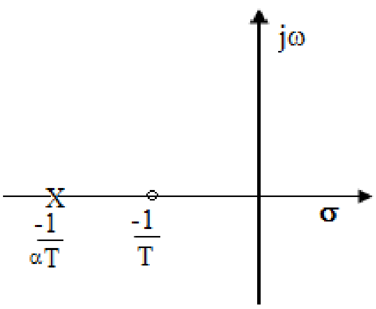
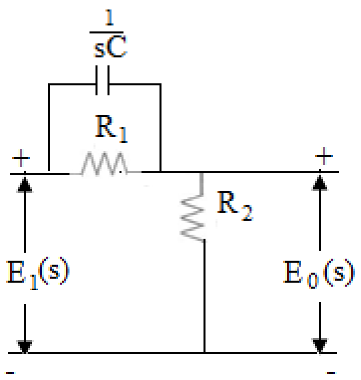
The lag compensator has a pole at $s = -\frac{1}{\beta T}$ and a zero at $s = -\frac{1}{T}$. The transfer function of a lag compensator is given by $Gc(s) = \frac{s + Zc}{s + Pc} = \frac{s + \frac{1}{T}}{s + \frac{1}{\beta T}}$ where, $T > 0$ *and* $\beta > 1$

Pole-zero diagram	Electrical circuit
	

32. **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.

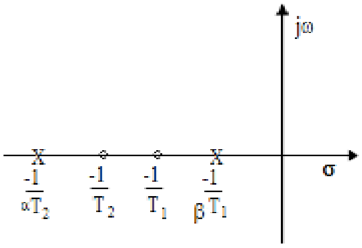
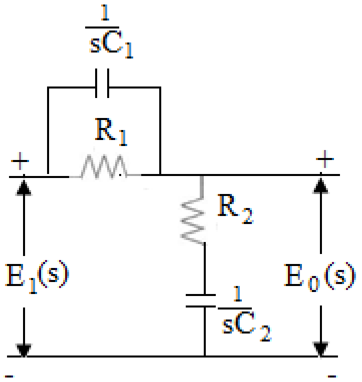
33. **Mention few applications of bode plot. (Nov 2015)**
- To determine stability of OP-AMP and Transistor.
- Stability analysis of control system
- Active filter circuits
- The frequency domain specifications can be easily determined
- The bode plot can be used to analyse both open loop and closed loop system.

34. **Draw the circuit of lead compensator and draw its pole zero diagram. (May 2011)**
The lead compensator has a pole at $s = -\frac{1}{\alpha T}$ and a zero at $s = -\frac{1}{T}$. The transfer function of a lag compensator is given by $Gc(s) = \frac{s + Zc}{s + Pc} = \frac{s + \frac{1}{T}}{s + \frac{1}{\alpha T}}$ where, $T > 0$ *and* $\alpha < 1$

Pole-zero diagram	Electrical circuit
	

35. **Draw the circuit of lead-lag compensator and draw its pole zero diagram.**
The transfer function of lead-lag compensator is given by,

$$Gc(s) = \frac{\left(s+\frac{1}{T_1}\right)\left(s+\frac{1}{T_2}\right)}{\left(s+\frac{1}{\beta T_1}\right)\left(s+\frac{1}{\alpha T_2}\right)}$$ where, $\beta > 1$ *and* $0 < \alpha < 1$

Pole-zero diagram	**Electrical circuit**
	

36. **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)**

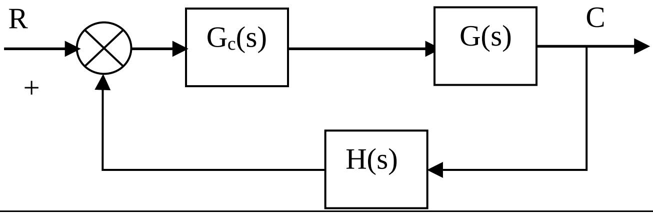
$$\gamma = 180° + \varphi_{gc}$$
$$\gamma = 180° - 125° = 55°$$

37. **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 the low 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.

38. **What is series compensation? (May 2017)**

When the compensator $[G_c(s)]$ is placed in series with the forward path transfer function of the plant[G(s)], the scheme is known as series compensation. It is also termed as cascade compensation. The figure shows the arrangements of series compensation.



39. **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)**

$$\gamma = 180° + \varphi_{gc}$$
$$\gamma = 180° - 125°$$
$$= 55°$$

40. **Differentiate phase lead and phase lag compensator.(Dec 2018)**

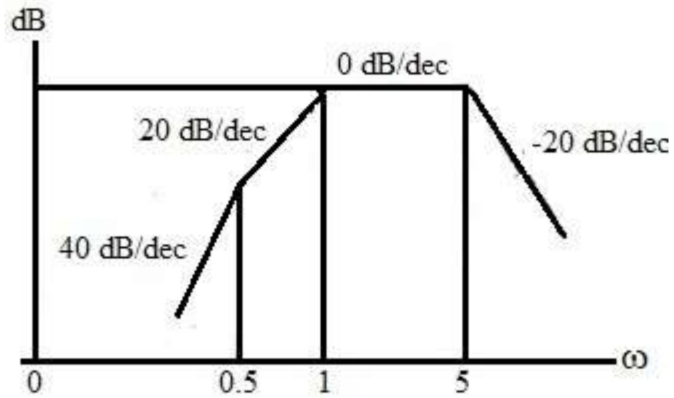
s.no	**Lead Compensator**	**Lag Compensator**
1.	A **lead compensator** adds positive phase over the specified frequency	**Lag compensator** adds negative phase to the system over the specified frequency range

2.	Transfer function of lead compensator, $$G_C(s)=\frac{s+z_c}{s+P_c}=\frac{s+\frac{1}{T}}{s+\frac{1}{\alpha T}}$$ The lead compensator has a pole at $S=-\frac{1}{\alpha T}$ and a zero at $S=-\frac{1}{T}$. Since α < 1 and T > 0,the zero of lead compensator is nearer to origin	The transfer function of a lag compensator is given by $Gc(s)=\frac{s+Zc}{s+Pc}=\frac{s+\frac{1}{T}}{s+\frac{1}{\beta T}}$ The lag compensator has a pole at $s=-\frac{1}{\beta T}$ and a zero at $s=-\frac{1}{T}$. where, $T>0$ *and* $\beta>1$	
3.	Lead compensator acts like PD controller improves transient state .	Lag compensator acts like PI controller and improves steady state.	

PART B

1.	A unity feedback control system has $G(s)=\frac{1}{s(1+0.1s)(1+s)}$. Draw the bode plot. Determine Gain margin, phase margin, ωgc and ωpc. Comment on the stability. **(Dec 2018)**
2.	The open loop transfer Function of a unity feedback system is given by, $G(s)=\frac{64(s+2)}{s(s+0.5)+(s^2+10s+64)}$.Sketch the bode plot and compute the gain and phase margins of the closed loop system. Also comment on the stability of the closed loop system. **(May 2019)**
3.	Given $G(s)=\frac{Ke^{-0.2s}}{s(s+2)(s+8)}$, find K for the following two cases: **(May 2011, Nov 2012)** (i) Gain margin equal to 6 db (ii) Phase margin equal to 45°
4.	i)Sketch the Bode magnitude plot for the transfer function $G(s)=\frac{100(1+0.1s)}{(1+0.01s)(1+s)}$ ii)Draw the polar plot for the following transfer function $G(s)=\frac{10(s+2)}{s(s+1)(s+3)}$ **(Nov 2011)**
5.	List out the frequency domain specifications of a standard second order system. Derive the expressions for resonant peak and Bandwidth of a second order system. **(NOV 2019)**
6.	Draw the pole-zero diagram of a lead compensator. Propose lead compensation using electrical network. Derive the transfer function. Draw the Bode plot. **(Nov 2012)**
7.	A unity feedback control system has $G(s)=\frac{10}{s(s+1)}$. Design a lead compensator such that the closed loop system will satisfy the following specifications Static velocity error constant = 20 sec; Phase margin = 50°, Gain margin =10db
8.	(i)For the following transfer function, $G(s)=\frac{K(s+3)}{s(s+1)(s+2)}$ sketch the Bode magnitude plot by showing slope contributions from each pole and zero. (ii) For an unity feedback system with closed loop transfer function $\frac{G(s)}{1+G(s)}$ derive the equations for the locus of constant M circles and constant N circles. **(May 2012)**

9.	Define all the frequency domain specifications of a second order control system after plotting the response. **(Nov 2015)**
10.	i)Write the procedure to obtain Nichol's chart from constant M circles. ii) Write a Matlab program to examine the stability using Bode plot, for the given transfer functions $G(s)=\frac{20e^{-0.2s}}{s(s+2)(s+8)}$. Explain the code (statements) as to what the variables and numbers mean and also what action is caused by each statement. State also how you will interpret the result. **(May 2012)**
11.	Consider a unity feedback open loop transfer function $G(s)=\frac{100}{s(1+0.1s)(1+0.2s)}$. Draw the Bode plot and find the phase and gain cross over frequencies, phase and gain margin and the stability of the system.**(May 2013)**
12.	Explain in detail the design procedure of lead compensator using Bode plot.**(May 2013)**
13.	For the following transfer function draw bode plot and obtain gain crossover frequency. $G(s)=\frac{20}{s(1+3s)(1+4s)}$ (**Nov2013**)
14.	Discuss in detail about lead and lag networks.(**Nov2013**)
15.	The open loop transfer function of a system is given by $G(s)H(s)=\frac{30}{s(1+0.5s)(1+0.08s)}$. Draw the Bode plot and determine Gain margin and Phase margin. (**May 2014**)
16.	(i)Sketch the polar plot of the unity feedback system with open loop transfer function $G(s)=\frac{1}{s(s+1)^2}$. Also find the frequency at which $\lvert G(j\omega)\rvert = 1$. (10)(**May 2014**) ii) What are the advantages and disadvantages of frequency response analysis?
17.	For the following transfer function draw the bode plot, find the gain and phase margin: **(May 2015)** $G(s)H(s)=\frac{5}{s(10+s)(20+s)}$
18.	The open loop transfer Function of a unity feedback system is given by, $(s)=\frac{50}{s(s+1)+(s+5)(s+10)}$. Sketch the polar plot, calculate the gain and phase margins of the closed loop system and comment on the stability of the closed loop system**.(May 2019)**
19.	The open loop transfer function of a unity feedback system is given by $G(s)=\frac{1}{s(s+1)(1+2s)}$. Sketch the polar plant and determine the gain and phase margin.
20.	i) Describe about Lead- Lag compensators design procedure. (ii) Write short notes on constant M and N circles. **(Dec 2014)**
21.	i)Write short notes on series compensation. **(May 2016)** ii) Write down the procedure for designing Lead compensator using Bode plot.
22.	The open loop transfer function of a unity feedback system is given by $G(s)=\frac{1}{(s)(1+s)^2}$. Sketch the polar plant and determine the gain and phase margin. **(Nov 2016)**
23.	i)Write down the procedure for designing Lag compensator using Bode plot. ii) State about Parallel feedback compensation. **(Nov 2016)**
24.	Plot the polar plot for the following transfer function. **(May 2017).**

	$G(s)=\frac{15}{(s+1)(3+s)(6+s)}$
25.	Discuss briefly about the lag, lead and lag-lead compensator with examples. **(May 2017)**
26.	A unity feedback system has $G(S)=\frac{K}{S(S+4)(S+10)}$ .Draw the bode plot. **(Nov 2017)**
27.	The open loop transfer function of a unity feedback system is $G(S)=\frac{K}{S(S+1)}$. It is desired to have the velocity error constant Kv=12 sec^{-1} and phase margin as 40°. Design a lead compensator to meet the above specifications.**(Nov 2017)**
28.	Discuss the procedure for constructing the bode magnitude plot and bode phase plot. **(May 2018)**
29.	A unity feedback system has an open loop transfer function, $G(S)=\frac{K}{S(1+2S)}$. Design a suitable lag compensator so that phase margin is 40 deg and the steady state error for ramp input is less than or equal to 0.2. **(May 2018)**
30.	An unity feedback has $G(s)=\frac{K}{S(1+0.2S)(1+0.05S)}$. Draw the polar plot. Find the K when gain margin =18 dB**.(Dec 2018)**
33.	An unity feedback has $G(s)=\frac{k}{s(s+4)(s+10)}$. Draw the bode plot. Find the K when phase margin =30 deg.
34.	Sketch the bode plot for the following transfer function and determine the system gain K for the gain cross over frequency to be 5 rad/ sec. $G(s)=\frac{Ks^2}{(1+0.2s)(1+0.02s)}$
35.	The open loop transfer function of a unity feedback control system is $G_f(s)=\frac{k}{s(s+1)(s+2)}$ Design a suitable lag-lead compensator so as to meet the following specifications: static velocity error constant Kv = 10 sec^{-1}, phase margin = 50deg and gain margin = 10db.
36.	Determine the transfer function for the given magnitude plot**.(Dec 2018)** 
37.	Describe the procedure for obtaining the polar plot for a system whose loop transfer function is $G(s)=\frac{4}{(s+2)(s+4)}$
38.	Design a lead compensator for the system $G(s)=\frac{1}{s(s+2)}$ with damping coefficient equal to 0.45, velocity error constant > 20 and small settling time.

39.	Analyze on lead, lag and lead lag compensators with neat diagram. Also explain their importance.
40.	The open loop transfer function of the plant is $$\frac{G(s)}{H(s)} = \frac{10e^{-S\tau_D}}{s(0.1s+1)(0.05s+1)}$$ Use Bode plot, find the gain and phase margin when τ_D=0. **(NOV 2019)**
41.	The open loop transfer function of a unity feedback system is G(s)=K/s(s+1). It is desired to have the velocity error constant K_v =12sec-^{1} and phase margin as 40. Design a lead compensator to meet the above specifications. **(NOV 2019)**

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 stability criterion

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

	-∞ to +∞.(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.	**What is meant by the term " magnitude criteria" in root locus technique?** The magnitude criteria states that $\lvert D(s)\rvert = 1$ $\lvert D(s)\rvert = K \frac{\lvert s+z_1\rvert \bullet \lvert s+z_2\rvert \bullet \lvert s+z_3\rvert \bullet \lvert s+z_4\rvert ---}{\lvert s+p_1\rvert \bullet \lvert s+p_2\rvert \bullet \lvert s+p_3\rvert \bullet \lvert s+p_4\rvert ---} = 1$ $= K \frac{\prod_{i=1}^{m} \lvert s+z_i\rvert}{\prod_{i=1}^{n} \lvert s+p_i\rvert} = 1$ $\lvert G(s)H(s)\rvert = K = \frac{\text{Product of length of vectors from open loop zeros to the point sa}}{\text{Product of length of vectors from open loop poles to the point sa}}$
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 $\angle D(s) = \pm 180^\circ (2q+1)$ $\because \sum_{i=1}^{m} \angle(s+z_i) - \sum_{i=1}^{m} \angle(s+p_i) = \pm 180^\circ (2q+1) \quad q = 0,1,2,...$
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 $= \frac{\pm 180^\circ (2q+1)}{n-m}$; $q = 0,1,2,3,....(n-m)$, 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.

21. **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.
(ii)It determines the stability of the closed-loop system from the open-loop transfer function without calculating the roots of the characteristic equation.

22. **What is the nature of locus of poles of second order closed loop system with constant Gain?**

The root locus is a straight line passing through origin at an angle θ with negative real axis.
$\theta = \cos^{-1} \zeta$
where ζ is damping ratio.

23. **State Routh's stability criterion. (Or) write the necessary and sufficient condition for stability in Routh's stability criteria. (May 2013, Nov 2015, May 2016,May 2017)**

A sufficient condition for stability is that all of the elements in the first column of the Routh array be positive. If this condition is not met, the system is unstable and the number of sign changes in the elements of the first column of the Routh array corresponds to the number of roots of the characteristic equation in the right half of the s – plane..
Necessary condition is that the coefficients of the characteristic polynomial should be positive.

24. **What are the effects of addition of open loop poles? (May 2010)**

Addition of open loop poles degrades the relative stability. System produces sluggish responses. Improves the Transient response

25. **State any two limitations of Routh stability criterion. (Nov 2011, Nov 2012)**

(i) Routh stability criterion is valid only for real coefficients of the characteristic equation.

	(ii) Routh stability criterion does not provide exact locations of the closed loop poles in left or right half of s-plane. (iii) Routh stability criterion does not suggest methods of stabilizing an unstable system. (iv) Routh stability criterion is applicable only to linear systems
26.	**State Nyquist stability criterion. (May 2010,May 2012, May 2013, Nov 2015, May 2017, Nov 2017)** 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 of s-plane poles of G(s)H(s). Then the closed loop system is stable. The Nyquist criterion for systems with poles on the imaginary axis.). This results from the requirement of the argument principle that the contour cannot pass through any pole of the mapping function. The most common case are systems with integrators (poles at zero). The stability of linear control system using the Nyquist Stability criterion are: i. No encirclement of -1+j0 point, implies the system is stable, ii. Anticlockwise encirclement of -1+j0 point, implies the system is stable, if the number of anticlockwise encirclements is same as the number of poles of G(S)H(S) in the right half of S plane. If the number of anticlockwise encirclements is not equal to number of poles on right half of S plane, then the system is unstable. Clockwise encirclement of -1+j0 point implies the system is unstable.(
27.	**What is the value of gain K at any point on root locus?** The value of K corresponding to dominant pole can be obtained from magnitude condition. Let K_{sd} be the value of gain at dominant pole (s_d) on root locus. $K_{sd} = \frac{product\,of\ length\ of\ vectors\ from\,open\,loop\ poles\,to\,do\min ant\ poles}{product\,of\ length\ of\ vectors\ from\,open\,loop\ poles\,to\,do\min ant\ zeros}$
28.	**How will find root locus on real axis? (May 2016)** First split the real axis into regions based on location of poles and zeros on the real axis. Consider a test point on the real axis. If the total number of poles and zeros on the real axis to the right of the test point is odd number then the selected region is root locus. If it is even number then the selected region is not a root locus.
29.	**What will be stability of the system when the roots of characteristics equation are lying on imaginary axis? (Nov 2017, May 2018)** If the characteristics equation has repeated roots, one or more non repeated in the jw axis, the system is unstable. If the roots of the characteristics equations have negative real parts, except for the presence of one or more non-repeated roots on the jw axis, the system is limitedly stable.
30.	**How do you define relative stability? (NOV 2019)** It is measure of how fast the transient dies out in the system. Relative stability is related to settling time, a system having poles away from the left half of imaginary axis is considered to be relatively more stable compared to a system having poles closed to imaginary axis
31.	**The Nyquist plot of G(jω)H(jω) for a closed loop system, passes through (-1+j0) point in the GH plane. What is the gain margin of the system in dB?(Dec 2018)** Gain Margin is calculated by taking inverse of the modulus of the gain where the Nyquist plot cuts the real axis. Gain margin=inverse of gain $Gain\ margin = 20\log\left(\frac{1}{1}\right) = 20\log 1 = 0\ dB$
32.	**Find the range of K for closed loop stable behaviour of system with characteristics equation $s^4+8s^3+36s^2+80s+K$ using Routh Hurwitz stability criterion.(Dec 2018)** Solution :

S^4	1	36	K
S^3	8	80	

$S^3/8$	1	10	
S^2	$\frac{36\times1-10\times1}{1}=26$	$\frac{1\times K-0}{1}=K$	
S^1	$\frac{26\times10-K}{26}=\frac{260-K}{26}$	0	
S^0	K		

For the system to be stable the first column should be +ve.

From S^1 it can be said that $\frac{260-K}{26}>0$

$260-K>0$

$K<260$

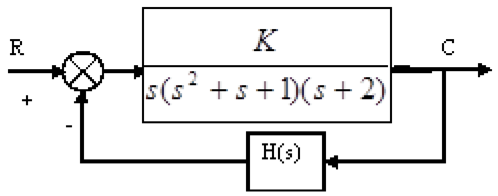
From S^0 it can be said that K>0

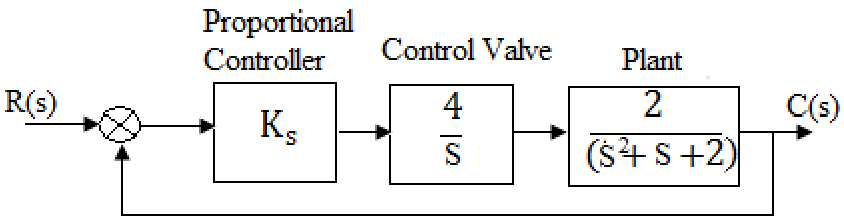
Therefore 0>K<260

PART B

1.	By Nyquist stability criterion determine the stability of closed loop system, whose open loop transfer function is given by $G(s)H(s)=\frac{s+2}{(s+1)(s-1)}$. Comment on the stability of open loop and closed loop systems. **(Nov 2009)**
2.	(i) Examine the stability of Routh's criterion $s^5+s^4+2s^3+2s^2+3s+15=0$ (8) (ii) Find range of values of K so that system with the characteristic equation $F(s)=s(s^2+s+1)(s+4)+k=0$, will be stable using Routh's criterion.(8)**(May 2009)**
3.	Draw the root locus for open loop transfer function of a unity feedback control system given by $G(s)=\frac{K}{s(s+1)(s+3)}$ and determine (i). The value of K for G=0.5, (ii). The value of K for marginal stability. (iii).The value of K at S= -4. **(May 2010)**
4.	An unity feedback control system has $G(s)=\frac{10}{s(s+1)(s+2)}$. Draw the Nyquist plot and comment on closed loop stability. **(May 2010)**
5.	The open loop transfer function of unity feedback control system is $G_f(s)=\frac{k}{(s+2)(s^3+10s^2+49s+100)}$. Using Routh stability criterion, calculate the range of 5.
6.	Sketch the Nyquist plot for a system with open loop transfer function $G(s)H(s)=\frac{k(1+0.4s)(s+1)}{(1+8s)(s-1)}$ and determine the range of k for which the system is stable. **(Nov 2011)**
7.	The open loop transfer Function of a unity feedback system is given by, $G(s)=\frac{K}{s(s+1)+(s+5)}$where K>0. Apply Nyquist stability criterion to determine a range of K over which the closed loop system will be stable. **(May 2019)**
8.	(i) A certain unity negative feedback control system has the following open loop transfer function $G(s)H(s)=\frac{k}{s(s+2)(s^2+2s+5)}$. Find the breakaway points and draw Root Locus for $0\le\omega\le\infty$. (12) **(Nov 2011)** (ii) List the advantages of Routh's array method of examining stability of a control system.

9.	(i) Construct Routh array and determine the stability of the system whose characteristics equation is $s^6+2s^5+8s^4+12s^3+20s^2+16s+16=0$.(6) ii) Sketch the Root locus of the system whose open loop transfer function is $G(s)=\frac{k}{s(s+2)(s+4)}$. Find the value of k so that the damping ratio of the closed loop system is 0.5 (10) **(May 2012, May 2013)**
10.	(i) Determine the range of K for stability of unity feedback system whose open loop transfer function is $G(s)=\frac{k}{s(s+1)(s+2)}$ using Routh stability criterion. (8) (ii) Draw the approximate root locus diagram for a closed loop system whose loop transfer function is given by $G(s)H(s)=\frac{k}{s(s+5)(s+10)}$. Comment on the stability. **(Nov 2012)**
11.	Sketch the root locus of the system having $G(s)=\frac{k(s+3)}{s(s+1)(s+2)(s+4)}$ **(May 2013)**
12.	Sketch the root locus for $GH(s)=\frac{k(s+2)(s+3)}{(s+1)(s-1)}$. **(Nov2013)**
13.	The open loop transfer function of a unity feedback control system is given by $GH(s)=\frac{k}{(s+2)(s+4)(s^2+6s+25)}$. By applying the Routh criterian, discuss the stability of the closed loop system as a function of K. **(Nov 2013)**
14.	Draw the root locus plot for the system whose transfer function $\frac{C(s)}{R(S)}=\frac{K}{s(s+4)(s^2+s+1)}$. **(Dec 2018)**
15.	Draw the root locus diagram for the loop transfer function $G(s)H(s)=\frac{K(s+6)}{s(s+4)}$ and calculate K for which the closed loop system will be critically damped. **(May 2019)**
16.	(i) The open loop transfer function is given by $G(s)=\frac{k}{s(1+0.1s)(1+s)}$. For this unity feedback system, determine the value of k so that the gain margin is 6dB. (8) (ii) By using Routh Criterion, determine the stability of the system represented by following characteristic equations $s^5+s^4+2s^3+2s^2+11s+10=0$. (8) **(May 2014)**
17.	A single loop negative feedback system has a loop transfer function $G(s)H(s)=\frac{K(s+6)^2}{s(s^2+1)(s+4)}$. Sketch the root locus as a function of K. Find the range of K for which the system is stable, K for which purely imaginary roots exist and find the roots. **(May 2015).**
18.	Describe the procedure for obtaining the root locus for a system. **(Nov 2015)(Nov 2016)(May 2017)**
19.	Determine closed loop stability of the system using Nyquist stability criterion $G(S)=\frac{2}{s^2(s+2)}$ **(Nov 2015)**
20.	Draw the Nyquist plot and find the stability of the following open loop transfer function of unity feedback control system $G(s)H(s)=\frac{K(s+1)}{s^2(s+10)}$ if the system is conditionally stable, find the range of K for which the system is stable. **(May 2015)**

21.	i) Using Routh Hurwitz criterion, determine the stability of a system representing the characteristic equation $s^6+2s^5+8s^4+12+s^3+20s^2+16s+16=0$ and comment on location of the roots of the characteristics equation. (8)**(May 2016)** (ii) Describe about Nyquist contour and its various segments. (8) **(May 2016)**
22.	(i) State Nyquist stability criterion and explain the three situations while examining the stability of the linear control system. (ii) Construct R-H criterion and determine the stability of a system representing the characteristics equation $s^5+s^4+2\ s^3+3s+5=0$. Comment on location of the roots of the characteristics equation. **(Nov 2016)**
23.	Determine the range of K for stability of unity feedback system using Routh stability criterion whose transfer function $\frac{C(s)}{R(s)} = \frac{K}{s(s^2+s+1)(s+2)+K}$ **(May 2017) or** Determine the range of K for stability of the system as shown in figure.**(May 2018)** 
24.	Explain briefly about the steps to be followed to construct a rrot locus plot of s given transfer function**.(May 2017)**
25.	Sketch the root locus plot for $G(S)H(S) = \frac{K(S^2-4S+20)}{(S+2)(S+4)}$. Find the gain K at the point where the locus crosses the imaginary axis. **(Nov 2017)**
26.	With neat steps write down the procedure for construction of root locus. Each rule give an example. **(Nov 2016)**
27.	Draw the Nyquist plot for the system, whose open loop transfer function is $G(s)H(s) = \frac{K(1+s)^2}{s^3}$. Determine the range of K for which closed loop system is stable. **(Dec 2018)**
28.	Sketch the root locus for the system whose loop transfer function is $G(S) = \frac{K}{S(S+1)(S+2)}$, H(S)=1. Determine the value of K such that the damping ratio of a dominant complex conjugate closed loop poles is 0.5. **(May 2018)**
29.	Draw the root locus diagram for a system open loop transfer function and then determine the value of k such that the damping ratio of the dominant closed loop poles is 0.4. Open – loop transfer function : $\frac{20}{s(s+1)(s+4)+20ks}$ **(May 2017)**
30.	Sketch the root locus for the open loop transfer function of unity feedback control system given below. $G(S) = \frac{k}{s(s^2+4s+13)}$ **(Dec 2014, May 2016)**
31.	(i) Obtain Routh array for the system whose characteristics polynomial equation is $s^6+2s^5+12s^3+20s^2+16s+16=0$. Check the stability. **(Dec 2014)** (ii) Define Nyquist stability criterion and explain the different situations of it.**(Dec 2014)**
32.	Sketch the Nyquist plot for a system with open loop transfer function $G(s)H(s) = \frac{k(1+0.4s)(s+1)}{(1+8s)(s-1)}$ and determine the range of K for which the system is stable.
33.	For a certain control system, , Sketch the Nyquist plot and determine the range of values of K for stability.**(May2009, May 2011, May 2012)**

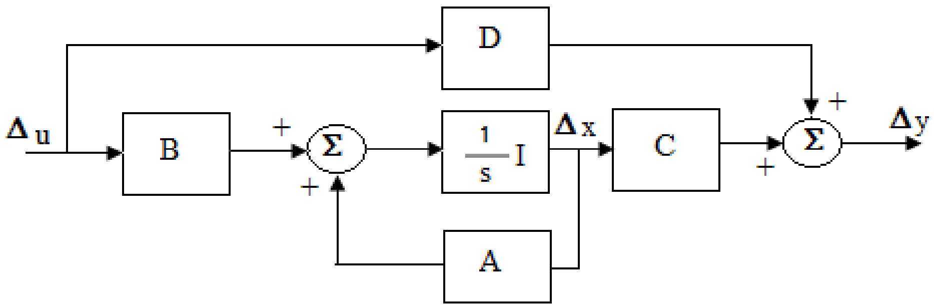
34.	Define Stability. With an example, explain the steps to be followed for Routh- Hurwitz criterion.**(Nov 2017).**
35.	Using Nyquist stability criterion, find the relative stability of the system whose open loop transfer is defined as $G(S)H(S)=\dfrac{K(s+1)}{s^2(s+2)(s+4)}$. **(May 2018)**
36.	Sketch the root locus diagram of the control system as shown in figure: find the value of the proportional controller gain K_1 to make the system is just unstable. **(NOV 2019)** 
37.	Use the Routh stability criterion to determine the location of roots on the s-plane and hence stability for the system represented by the characteristic equation $S^6+S^5+3S^4+5S^2+2S+1=0$. **(NOV 2019)**
38.	Using Nyquist stability criterion, find the relative stability of the system whose open loop transfer function is defined as G(s) H(s) = $\frac{K(s+1)}{s^2(s+2)(S+4)}$ **(NOV 2019)**

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 digital control 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 n^{th} order system? (Dec 2014, Nov 2017)**

State model of n^{th} order system:

State equation : $\dot{X} = AX + BU$

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \vdots \\ \dot{x}_n \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \\ \vdots \\ x_n(t) \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1m} \\ b_{21} & b_{22} & \cdots & b_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ b_{n1} & b_{n2} & \cdots & b_{nm} \end{bmatrix} \begin{bmatrix} u_1(t) \\ u_2(t) \\ \vdots \\ u_m(t) \end{bmatrix}$$

[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 : $Y = CX + DU$

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_p \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ c_{p1} & c_{p2} & \cdots & c_{pn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} + \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1m} \\ d_{21} & d_{22} & \cdots & d_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ d_{p1} & b_{p2} & \cdots & b_{pm} \end{bmatrix} \begin{bmatrix} u_1(t) \\ u_2(t) \\ \vdots \\ u_m(t) \end{bmatrix}$$

[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:

$$H(s) = \frac{Y(s)}{U(s)} = \frac{b_0 s^n + b_1 s^{n-1} + \cdots + b_{n-1} s + b_n}{s^n + a_1 s^{n-1} + \cdots + a_{n-1} s + a_n}$$

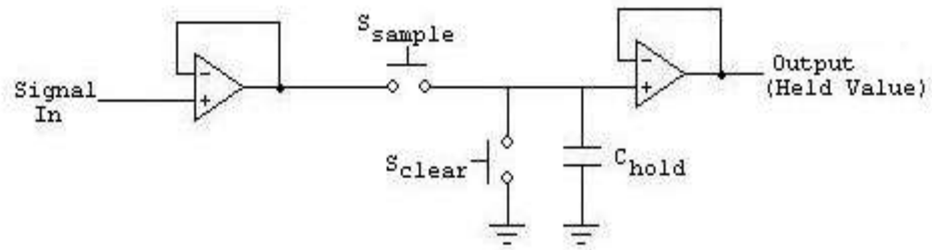
The observable canonical state space model form is

$$a = Aq + Bu; \quad A=\begin{bmatrix} -a_1 & 1 & 0 & .. & 0 \\ -a_2 & 0 & 1 & 0 & : \\ : & : & 0 & .. & 0 \\ -a_{n-1} & 0 & : & .. & 1 \\ -a_n & 0 & 0 & .. & 0 \end{bmatrix}; \quad B=\begin{bmatrix} b_1 & -a_1 b_0 \\ b_2 & -a_2 b_0 \\ : & \\ b_{n-1} & -a_{n-1} b_0 \\ b_n & -a_n b_0 \end{bmatrix}$$

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:

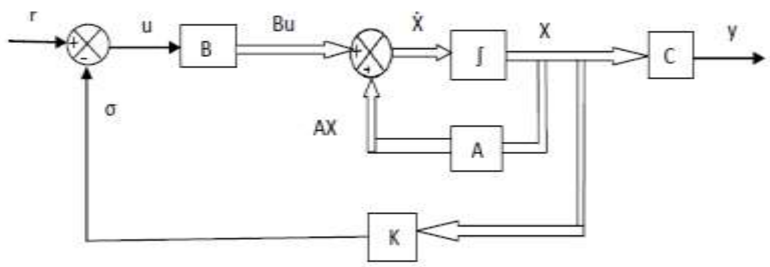
a) Systems are highly accurate, fast and flexible.
b) Digital transducers used in the system have better resolution
c) The digital components are less affected by noise, non-linearites.

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

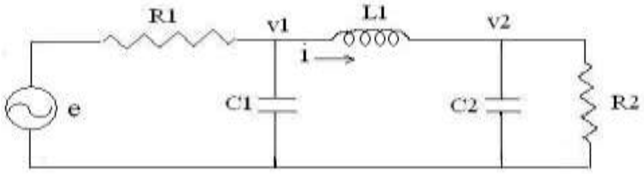
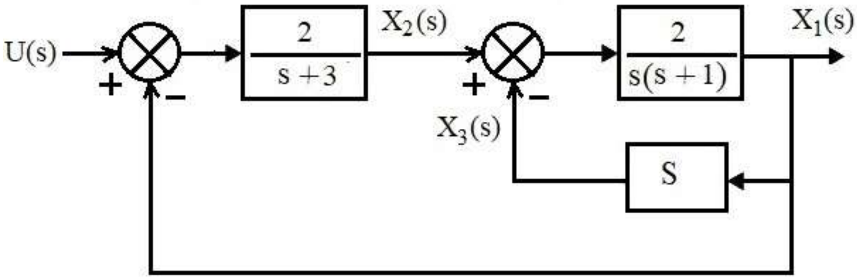
24. **An LTI system given by the following state variable description:**
Determine whether the system is controllable or not. (May 2019)

Sol:

	$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$ $B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$ $C = \begin{bmatrix} 1 & 0 \end{bmatrix}$ By kalman's test $Q_C = \lvert B \quad AB \rvert \neq 0$ Then the system is controllable. $Q_C = \begin{vmatrix} 0 & 1 \\ 1 & -3 \end{vmatrix} = -1$ The determinant of $Q_C \neq 0$. Therefore the system is controllable.
25.	**How the modal matrix is determined? (May 2012)** The modal matrix M can be formed from eigenvectors. Let $m_1, m_2, m_3, \ldots m_n$ be the eigen vectors of a n^{th} order system. Now the modal matrix M is obtained by arranging all the eigen vectors column wise as shown below. Modal matrix = M = $[\, m_1\ m_2\ m_3\ ,\ldots\ m_n]$
26.	**Give the concept of controllability. (Nov2013)** A system is said to be completely state controllable if it is possible to transfer the system state from any initial state $X(t_0)$ at any other desired state X(t), in specified finite time by a control vector U(t). Controllability test is necessary to find the usefulness of a state variable. If the state variables are controllable then by controlling the state variables the desired outputs of the system are achieved.
27.	**Define observability (May 2015)** 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 $t_0 \leq t \leq t_f$.
28.	**What is the need for observability test?** The observability test is necessary to find weather the state variables are completely measurable are not. If the state variables are measurable then the state of the system can be determined by practical measurements of the state variables.
29.	**What is pole placement by state feedback?(Dec 2016)** The pole placement by state feedback is a control system design technique, in which the state variables are used for feedback to achieve the desired closed loop poles.
30.	**What is necessary condition to be satisfied for design using state feedback?** The state feedback design requires arbitrary pole placement to achieve the desired performance. The necessary and sufficient condition to be satisfied for arbitrary pole placement is that the system be completely state controllable.
31.	**What is control law?** In control system design using state variable feedback, the equation u=r-KX is called control law. Where, u=input to the plant; r =input to the system with state feedback; X=state vector; K=state feedback gain matrix
32.	**Draw the block diagram of a system with state feedback** 

33.	**What is pulse transfer function?** Pulse transfer function is the mathematical model of discrete time system. It is the impulse response of the system representation in z- domain. It is also define as the ratio of z-transform of input signal of the system. Pulse transfer function: $H(z)=\frac{C(z)}{R(z)}$ Where C(z) is z transform of output signal and R(z) z- transform of input signal.
34.	**The z-transfer function of an open loop system is given by** $G(Z)=\frac{2(Z-1.5)}{(Z-0.5)(Z+0.5)}$ **Is the open loop system stable? Justify.(May 2019)** The condition of open loop control system is absolutely stable, when all the poles of the open loop transfer function present with in the unit circle. In this problem the two poles lies inside the unit circle. So the system is said to be stable List the methods used to test the stability of linear discrete time system. The methods available to test the stability of linear discrete time systems are i)Jury's stability test ii)Bilinear transformation
35.	**List the methods used to test the stability of linear discrete time system.** The methods available to test the stability of linear discrete time systems are **i)Jury's stability test** **ii)Bilinear transformation**

PART B

1.	i) Using cascade method decompose the transfer function $\frac{Y(s)}{U(s)}=\frac{s+3}{(s+1)(s+2)}$ **(May 2010)** ii) Obtain the state space representation for electrical network shown in fig below.  Δ
2.	i) Determine the transfer matrix from the data given below. **(May 2010)** $A=\begin{bmatrix}-3 & 1\\ 0 & -1\end{bmatrix},\ B=\begin{bmatrix}1\\1\end{bmatrix},\ C=\begin{bmatrix}1 & 1\end{bmatrix},\ D=0.$ ii) The transfer function of a control system is given by $\frac{Y(s)}{U(s)}=\frac{s+2}{s^3+9s^2+26s+24}$. Check the controllability.
3.	Write the state equations for the system shown below in which x1, x2 and x3 constitute the state vector. (16) **(May 2011)**  Determine whether the system is completely controllable and observable.
4.	The state space representation of a system is given below. Obtain the transfer function.**(May 2011)**

<table>
<tr><td></td><td>

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -2 & 1 & 0 \\ 0 & -3 & 1 \\ -3 & -4 & -5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u \quad y = \begin{bmatrix} 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

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<tr><td>5.</td><td>

A system is represented by the state equation X=AX+BU; Y=CX where $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -1 & 1 \\ 0 & -1 & -10 \end{bmatrix}, B = \begin{bmatrix} 0 \\ 0 \\ 10 \end{bmatrix} \text{ and } C = [100].$ Determine the transfer function of the system. **(May 2013)**

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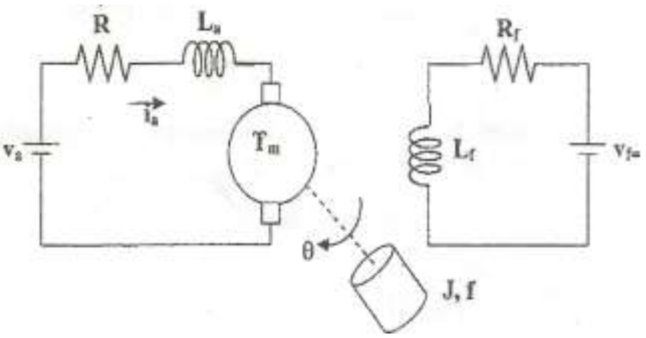
<tr><td>6.</td><td>

Obtain the state space representation of armature controlled D.C. motor with load shown below



Choose the armature current i_a, the angular displacement of shaft Θ, and the speed $\frac{d\theta}{dt}$ as state variables and Θ as output variable.**(May 2012)**

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<tr><td>7.</td><td>

(i) The state model matrices of a system are given below. Evaluate the observability of the system using Gilbert's test. (10) **(May 2012)**

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & -1 \\ 0 & -2 & -3 \end{bmatrix}, B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \text{ and } C = \begin{bmatrix} 3 & 4 & 1 \end{bmatrix}.$$

(ii) Find the controllability of the system described by the following equation. (6)

$$\dot{X} = \begin{bmatrix} -1 & -1 \\ 2 & -1 \end{bmatrix} \begin{bmatrix} X_1 \\ X_1 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} U(t)$$

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<tr><td>8.</td><td>

A system is characterized by the transfer function $\frac{Y(s)}{U(s)} = \frac{3}{s^3 + 5s^2 + 11s + 6}$. Identify the first state as the output. Determine whether or not the system is completely controllable and observable. **(May 2013)**

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<tr><td>9.</td><td>

For the given state variable representation of a second order system given below find the state response for a unit step input and by using the discrete time approximation. **(Nov 2013)(Dec 2018)**

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \end{bmatrix} [u] \begin{bmatrix} x_1 & 0 \\ x_2 & 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

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<tr><td>10.</td><td>

Consider the system with the state equation. Check the controllability of the system. **(Nov 2013)**

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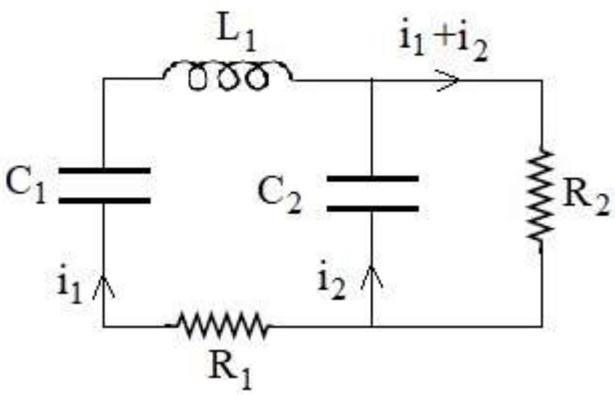
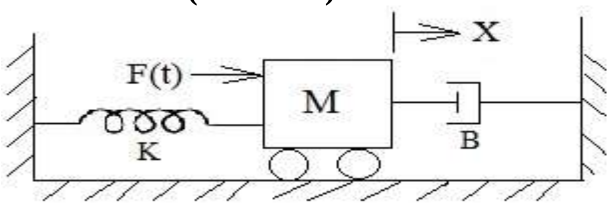
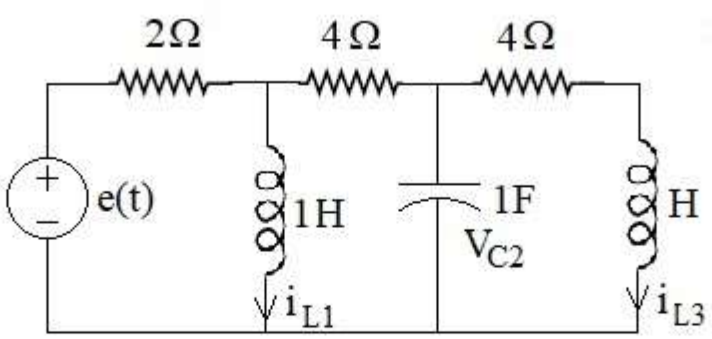
	$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix}=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ -6 & -11 & -6\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}+\begin{bmatrix}0\\ 0\\ 1\end{bmatrix}u$
11.	(i) Check the controllability of the following state space system. **(May 2014)** $\dot{x}_1 = x_2 + u_2$ $\dot{x}_2 = x_3$ $\dot{x}_3 = -2x_2 - 3x_3 + u_1 + u_2$ (ii) Obtain the transfer function model for the following state space system. (8) $A=\begin{bmatrix}0 & 1\\ -6 & -5\end{bmatrix}$ $B=\begin{bmatrix}1\\ 0\end{bmatrix}$ $C=\begin{bmatrix}1 & 0\end{bmatrix}$ $D=\begin{bmatrix}0\end{bmatrix}$
12.	Consider a system with state – space model given below. $\begin{bmatrix}\dot{X}_1\\ \dot{X}_2\\ \dot{X}_3\end{bmatrix}=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ -1 & -5 & -1\end{bmatrix}X+\begin{bmatrix}0\\ 5\\ -24\end{bmatrix}U; Y=\begin{bmatrix}1 & 0 & 0\end{bmatrix}X+\begin{bmatrix}0\end{bmatrix}U$ Verify that the system is observable and controllable. **(May 2015)**
13.	Determine the state model in canonical form. Draw the block diagram
14.	Explain how controllability and observability for a system can be tested with an example **(Nov 2015)**
15.	(i) Test the controllability & observability of the system by any one method whose state space representation is given as **(May 2016, Nov 2016, Nov 2017(13))** $\begin{bmatrix}\dot{X}_1\\ \dot{X}_2\\ \dot{X}_3\end{bmatrix}=\begin{bmatrix}0 & 0 & 1\\ -2 & -3 & 0\\ 0 & 2 & -3\end{bmatrix}\begin{bmatrix}X_1\\ X_2\\ X_3\end{bmatrix}+\begin{bmatrix}0\\ 2\\ 0\end{bmatrix}$u; $y=\begin{bmatrix}1 & 0 & 0\end{bmatrix}\begin{bmatrix}X_1\\ X_2\\ X_3\end{bmatrix}$
16.	(i) Construct a state model for a system characterized by the differential equation **(May 2016)** $\frac{d^3y}{dt^3}+6\frac{d^2y}{dt^2}+11\frac{dy}{dt}+6y+u=0$
17.	Construct the state model of the following electrical system. **(Nov 2016)** 

18.	A system is characterized by transfer function $\frac{Y(s)}{U(s)} = \frac{2}{s^3 + 6s^2 + 11s + 6}$. Find the state and output equation in matrix form and also test the controllability and observability of the system. **(May 2017)**
19.	Obtain a state-space equation and output equation for the system defined by $\frac{Y(S)}{U(S)} = \frac{2s^3 + s^2 + s + 2}{s^3 + 4s^2 + 5s + 2}$. **(May 2018)**
20.	Obtain a state-space equation and output equation for the system defined by $\frac{Y(S)}{R(s)} = \frac{S^3 + 5s^2 + 6s + 1}{S^3 + 4s^2 + 3s + 3}$ Also check for controllability and observability. **(Dec 2018)**
21.	For a system represented by state equation X(t) = A X(t). The response is $X(t) = \begin{bmatrix} e^{-2t} \\ -2e^{-3t} \end{bmatrix}$ when $X(0) = \begin{bmatrix} 1 \\ -2 \end{bmatrix}$ and $X(t) = \begin{bmatrix} e^{-2} \\ -e^{-t} \end{bmatrix}$ when $X(0) = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$. Determine the system matrix and transition matrix. **(May 2017)**
22.	Test the controllability and observability of the system whose state space representation is given as **(Dec 2014)** $\begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 2 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix} u$; $y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix}$
23.	(i) Obtain the state model of the system described by the following transfer function. $\frac{y(s)}{u(s)} = \frac{5}{s^2 + 6s + 7}$. **(May 2014)** (ii) Obtain the state transition matrix for the state model whose system matrix A is given by $A = \begin{bmatrix} 1 & 1 \\ 0 & 0 \end{bmatrix}$
24.	(i) Find the state variable equation for a mechanical system (spring-mass-damper system) shown below. **(Nov 2011)** 
25.	(ii) A LTI system is characterized by the state equation $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} [u]$ where u is a unit step function. Compute the solution of these equations assuming initial conditions $x_0 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$
26.	For the circuit shown in figure determine the state equation.

	 $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = A \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + Be(t)$
27.	Obtain a state space model for an LTI system whose transfer function is given by $G(s) = \frac{-2s+1}{s^2+5s^2+3s+1}$ **(May 2019)**
28.	Obtain the transfer function of LTI system and also check the stability of the system $X = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} U; Y = \begin{bmatrix} 1 & 0 \end{bmatrix} X$ and also check the stability of the system.
29.	The state model of the system is given by, $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_3 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix} u; y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$ Determine whether the system is completely controllable or not. **(NOV 2019)**
30.	Obtain the state model of the system whose transfer function is given as **(NOV 2019)** $\frac{Y(s)}{U(s)} = \frac{10}{s^3 + 4s^2 + 2s + 1}$
31.	Obtain a state space model for an armature controlled D.C. motor. Neglect load torque, assume armature inductance to be zero and consider angular position of the motor shaft as the output. Use standard notations. **(MAY 2019)**