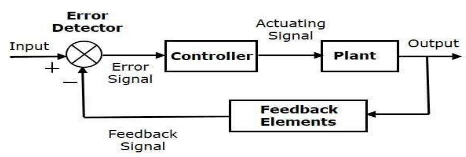
UNIT I – SYSTEMS AND REPRESENTATION

PART A

1) Mention the basic elements of a control system. (Nov 2014) (May/June 2016)

Error detector or comparator, controller, actuator or final control element, plant (system to be controlled) and feedback element (sensor or transmitters) are the basic elements of a control system.



2) Define open loop and closed loop system. (Nov 2017)

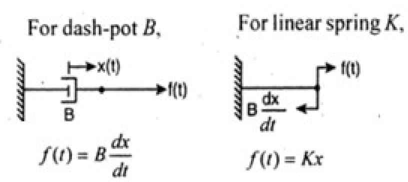
The control system in which the output quantity has no effect upon the input quantity is called open loop control system. The input has no feedback from the output.

The control system in which the output has an effect upon the input quantity so as to maintain the desired output values are called closed loop control system

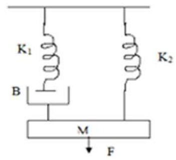
3) Distinguish between open loop and closed loop system (Nov 2019)

Sl. No	Open loop	Closed loop
1.	Any Change in output has no effect on the input.	Changes in output, affects the input which of possible by use of feedback.
2.	Feedback element is absent.	Feedback element is present.
3.	Simple and economical	Complex and costly
4.	They are generally stable	Great efforts are needed to design a stable system
5.	These are not reliable	These are reliable
6.	If calibration is good, they perform accurately	They are accurate because of feedback
7.	Highly affected by nonlinearities	Reduced effect of nonlinearities

4)	**What are the advantages and disadvantages of open loop control systems? (June2014)** Advantages 1. Open loop systems are simple in design and hence economical. 2. Very much convenient when output is difficult to measure. 3. The open loop systems are easier to construct. 4. Generally open loop systems are stable. Disadvantages 1. The open loop systems are not reliable. 2. The changes in the output due to external disturbances are not corrected automatically. 3. It cannot sense internal disturbances.
5)	**State any two advantages of feedback control system (or) State the advantages of closed loop system over open loop system (May/June 2015)** i) The controlled variable accurately follows the desired value. The feedback in the control loop allows accurate control of the output. ii) It greatly improves the speed of its response.
6)	**Why closed loop systems have a tendency to oscillate?** Controller takes corrective action based on the difference between input and feedback from the output. The output depends upon the controller action and so it has the tendency to oscillate.
7)	**Why negative feedback is preferred in control systems? (Nov 2016) (May 2017)** The negative feedback results in better stability in steady state and rejects any disturbance signals. Negative feedback leads to a tight control situation thereby the corrective action taken by the controller forces the controlled variable toward the set point.

8)	**List the characteristics of negative feedback in control system. (April/May2018)** • 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)	**What is the mathematical model of a system?** Mathematical model is the mathematical representation of the physical model of a system through use of appropriate physical laws. For most physical systems they are characterized by differential equations. A mathematical model may either be time variant or time invariant.
10)	**Define the Transfer function of a system. (Nov2010, Nov 2013) (Nov2014) (May 2021)** 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.
11)	**Write the force balance equation of ideal dashpot and ideal spring. (May 2015)** 
12)	**State the laws governing mechanical rotational elements.** Newton's law, which states that the applied torque will be equal to the sum of torque produced by all mechanical rotational elements (moment of inertia, viscous friction coefficient, torsional spring stiffness)
13)	**What are the basic elements used for modeling mechanical translational system. (Nov 2017)** Mass(M), spring(K) and dashpot (B) are three basic elements used for modeling mechanical translational system.

14) **Write the differential equations of the mechanical system shown in figure**



$$B\frac{d}{dt}(x_1 - x_2) + K_1 x_2 = 0$$

$$M\frac{d^2 x_2}{dt^2} + B(x_2 - x_1) + K_2 x_2 = F(t)$$

15) **Define servo mechanism. (Nov 2018)**

The servomechanism is a feedback control system in which the output is mechanical position (or) time derivatives of position (e.g. velocity & acceleration).

16) **What do you mean by analogous system?**

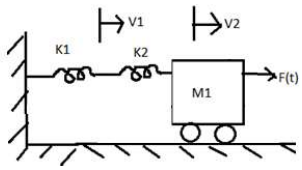
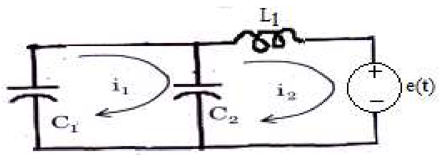
If two systems are said to be analogous to each other if the following two conditions are satisfied.

- The two systems are physically different
- Differential equation modelling of these two systems are same

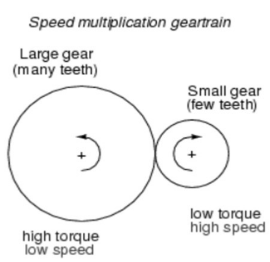
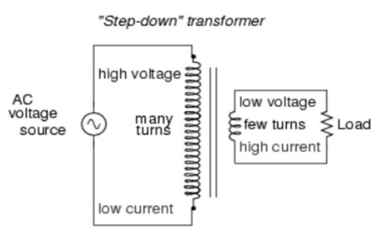
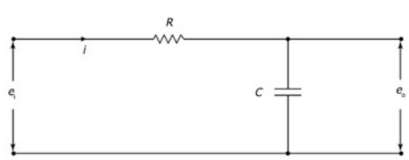
Electrical systems and mechanical systems are two physically different systems. There are two types of electrical analogies of translational mechanical systems. Those are force voltage analogy and force current analogy.

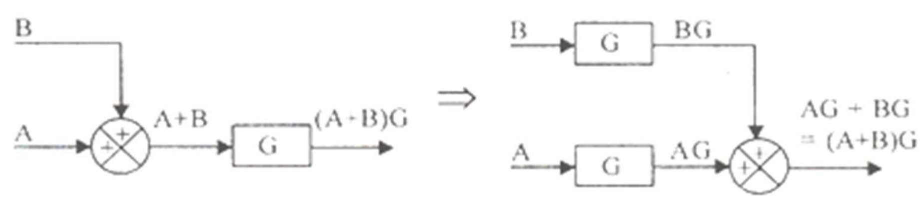
17) **Mention the equivalent electrical elements for the mass, damper, spring elements in mechanical system. / List the two types of electrical analogous for mechanical system.(May 2022)**

Mech.System Components	**Equivalent Electrical Elements**	
	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)

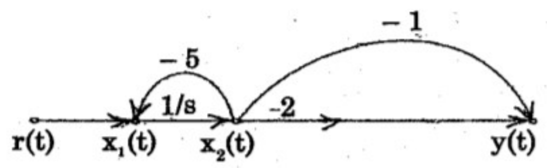
18)	**For the mechanical system shown in figure 1. Draw the corresponding Force-Voltage analogy circuit. (May 2019)**  
19)	**Tabulate the parameters of the translational and rotational systems. (May 2019)**

S.No	Mechanical Translational system	Mechanical Rotational System
1.	Force (f)	Torque (T)
2.	Velocity (v)	Angular velocity (ω)
3.	Displacement (x)	Angular displacement(θ)
4.	Frictional Coefficient of Dashpot (B)	Rotational coefficient of dashpot (B)
5.	Mass (M)	Moment of Inertia (J)
6.	Stiffness of spring (K)	Stiffness of spring (K)

20)	**What is electrical analogous of a gear?**  
21)	**Draw the electrical analog of thermometer. (Nov 2015)** The thermometer is assumed to have a thermal capacitance C which stores heat and thermal resistance R which limits that flow. 

22)	**What is block diagram? State its components. (May 2017)** A Block Diagram of a system is a pictorial representation of the functions performed by each component of the system and shows the flow of signals. The basic elements of block diagram are blocks, branch point and summing point.
23)	**What are the disadvantages of block diagram representation? (Nov 2018)** i) Not suitable for MIMO system ii) Not suitable for nonlinear system iii) Reduction of block diagram is becoming tedious for complex systems. iv) It is time consuming.
24)	**Write the expressions for Mason's gain formula. (May2018)** According to Mason's Gain formula, Overall gain, $T(s) = \frac{\sum\limits_{k=1,2...} P_k \Delta_k}{\Delta}$ Where, T = Transfer function of the system, P_k= forward path gain of k^{th} forward path Δ = 1 - (sum of individual loop gain) + (sum of gain products of all possible Combinations of two non-touching loops) - (sum of gain products of all possible combination of three non-touching loops) +.................. $\Delta_K = \Delta$ of the K^{th} forward path.
25)	**What is the advantage of Signal flow graph method?** (i) It follows a generalized procedure (ii) It is easier to simplify even if the system has complex structures (iii) Signal flow graph has a systematic approach, whereas block diagram reduction depends on the complexity of the system.
26)	**Represent the rule for moving a summing point ahead of a block. (May 2022)** 

27)	**Find the transfer function for the signal flow graph showing in figure below.(Nov 2019)**



Forward Paths Gain:

$$P_1 = -\frac{2}{s}$$

$$P_2 = -\frac{1}{s}$$

Individual loop Gain:

$$P_{11} = -\frac{5}{s}$$

Calculation of Δ and Δ_K :

Δ = 1-P_{11} = 1+(-5/s) $= \frac{(s+5)}{s}$

$\Delta_1 = 1$, $\Delta_2 = 1$

Transfer Function:

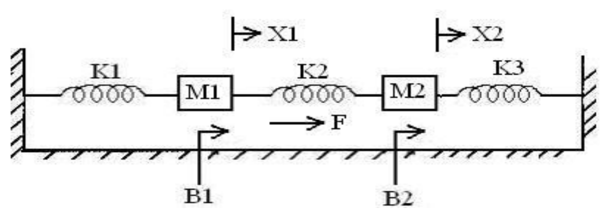
T =$\sum P_k \Delta_k / \Delta = (P_1 \Delta_1 + P_2 \Delta_2)/ \Delta$

$$T(s) = \frac{\left[-\frac{2}{s}\right][1] + \left[-\frac{1}{s}\right][1]}{\frac{(s+5)}{s}} = \frac{\left[-\frac{3}{s}\right]}{\frac{(s+5)}{s}} = \frac{-3}{s+5}$$

28)	**What are the memory elements in mechanical translational and electrical system?(May 2021)**

Mechanical Translational System Components	**Equivalent Electrical Elements**	
	Force – Voltage analogous	**Force – Current analogous**
Mass	Inductance (L)	Capacitance (C)

Spring	Reciprocal of capacitance (1/C)	Reciprocal of inductance (1/L)

<table>
<tr><th colspan="2">PART B</th></tr>
<tr><td>1)</td><td>(i) Compare open loop and closed loop systems with examples. (May 2016) (May 2017) (Nov 2018)
(ii)Derive the transfer function for an armature-controlled dc motor. (Nov 2015) (Nov 2018) (May 2021)</td></tr>
<tr><td>2)</td><td>Define transfer function and derive the transfer function of field control DC servomotor. (May 2019) (May 2022)</td></tr>
<tr><td>3)</td><td>Write the differential equations governing the behaviour of the mechanical system shown in figure below. Obtain an analogous electric circuit based on force current analogy. (April 2014)

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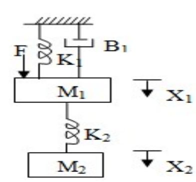
<tr><td>4)</td><td>Write the differential equations governing the behaviour of the mechanical system shown in figure below. Draw the force voltage and force current electrical analogous circuits and verify by writing mesh and node equations. (April 2011)

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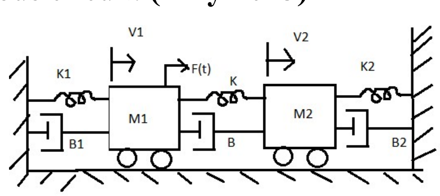
<tr><td>5)</td><td>Write the differential equations governing the system and draw the force voltage and force current analogous circuit. (May 2015)

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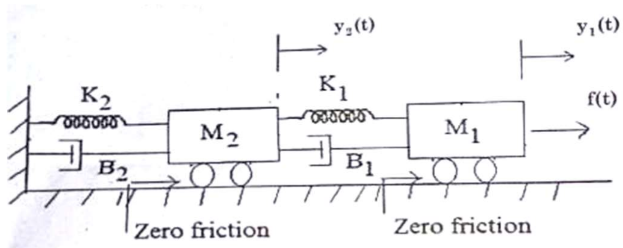
<table>
<tr><td>6)</td><td>For the given system
(a)Draw the mechanical network diagram and hence write the differential equations describing the behavior of the system
(b)Draw the force voltage and force current electrical analogous

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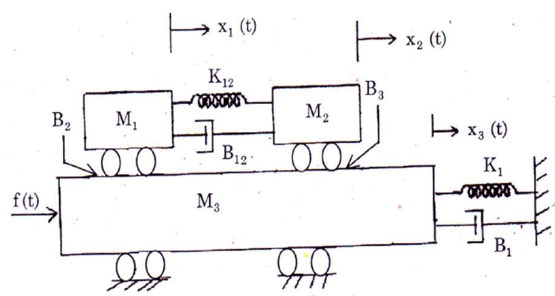
<tr><td>7)</td><td>Write the differential equations governing the mechanical system shown in the figure. Draw the force –voltage and force current analogous circuits. (Nov 2016)(Probable Part-C)

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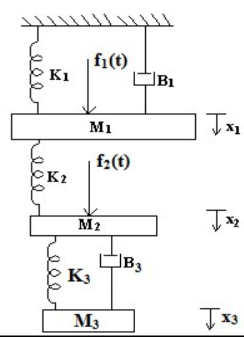
<tr><td>8)</td><td>Write the differential equation governing the mechanical translational system shown in figure. Draw the electrical equivalent analogy circuit. (May 2017) (May 2018)

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<tr><td>9)</td><td>Find the transfer function $\frac{Y_2(s)}{f(s)}$. (Nov 2017)</td></tr>
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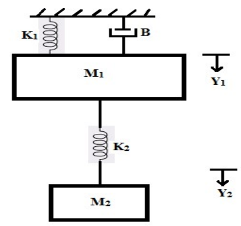
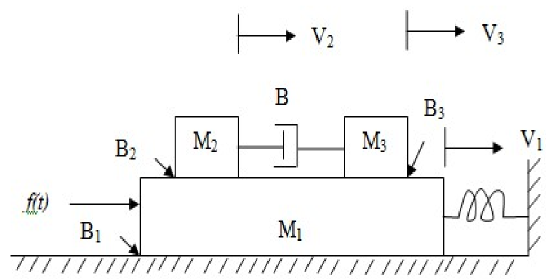
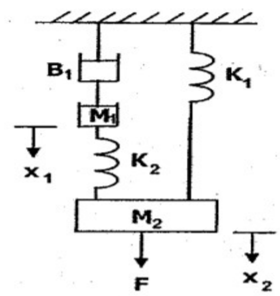
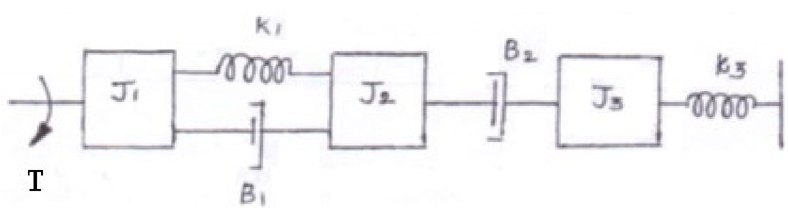
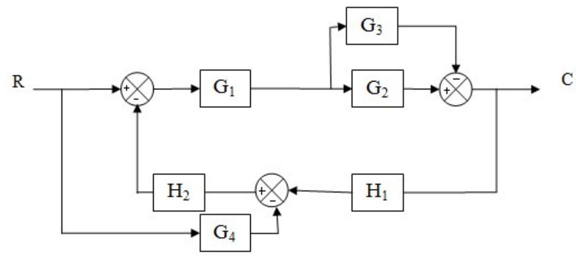
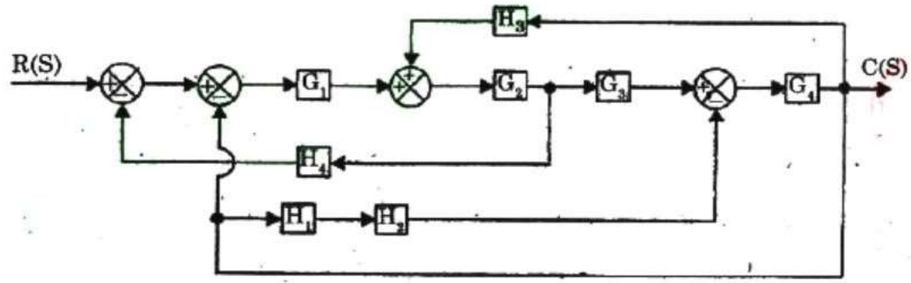
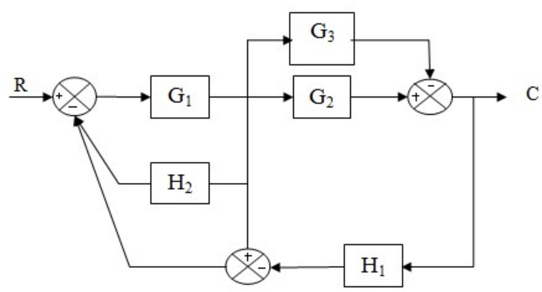
	
10)	Obtain the transfer function of the mechanical systems shown in the following figures. **(Nov 2018) (Probable Part-C)** 
11)	Find the transfer function $X_2(s)/F(s)$ for the figure shown below. **(Nov 2019)** 
12)	Write the differential equations governing the mechanical rotational system shown in the figure. Draw the both electrical analogous circuits**. (May 2016)** 
13)	Using block diagram reduction techniques find the closed loop transfer functions of the following system and verify it by using signal flow graph method. **(April 2011) (May 2019)**



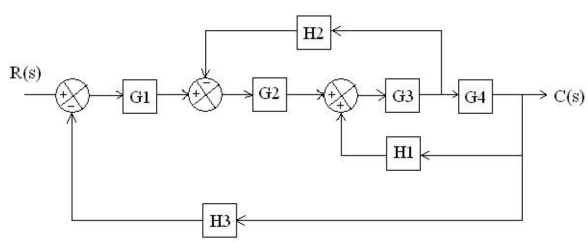
14) The block diagram of a closed loop system is shown in fig. using block diagram reduction technique; determine the closed loop transfer function. **(May 2018)**



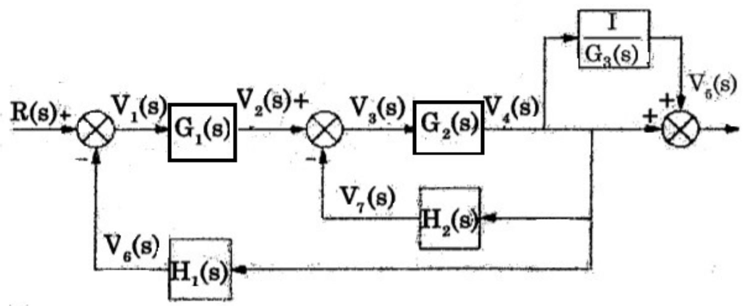
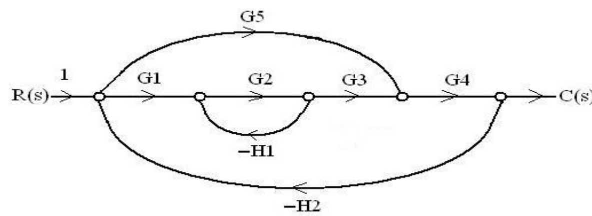
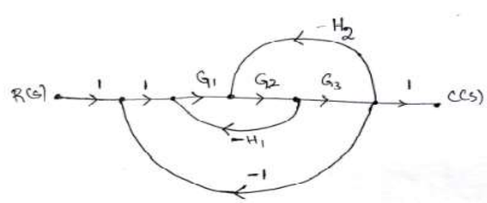
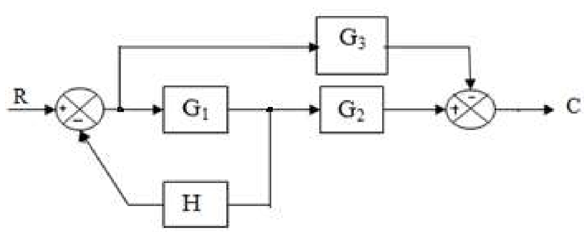
15) Draw the signal flow graph and evaluate the closed loop transfer function of a system whose block diagram is given in the following figure.

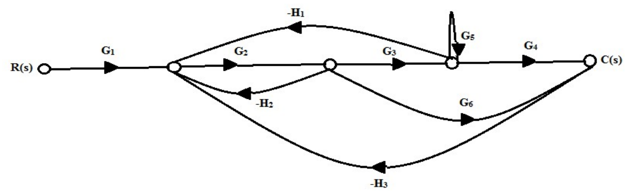


16) Using block diagram reduction rules, convert the block diagram to a simple loop. **(Nov 2014)**

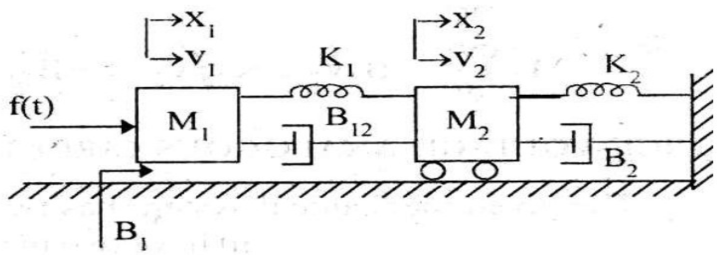


17) Reduce the block diagram shown in figure below. **(Nov 2019)**

	
18)	Consider the signal flow graph shown in figure. Obtain the closed loop transfer function C(s)/R(s) by the use of Mason's gain formula. **(April 2014)** 
19)	Obtain the transfer function using mason's gain formula for the given system. **(May 2015).** 
20)	For a non-unity negative feedback control system whose open loop transfer function is G(s) and feedback path transfer function is H(s), obtain the control ratio using mason's gain formula. **(Nov 2015)**
21)	Convert the given block diagram shown in the figure to signal flow graph and determine the closed loop transfer function C(S)/R(S **.(May 2016)** 
22)	Find the overall gain $\frac{C(s)}{R(s)}$ for the signal flow graph shown in Fig. **(Nov 2017)**



23) Write the differential equations governing the mechanical system shown in Fig.1. Draw the force-voltage and force-current electrical analogous circuits and verify by writing mesh and node equations. **(May 2022)**



24) Write the rules of block diagram reduction technique. **(May 2022)**

UNIT II – TIME RESPONSE

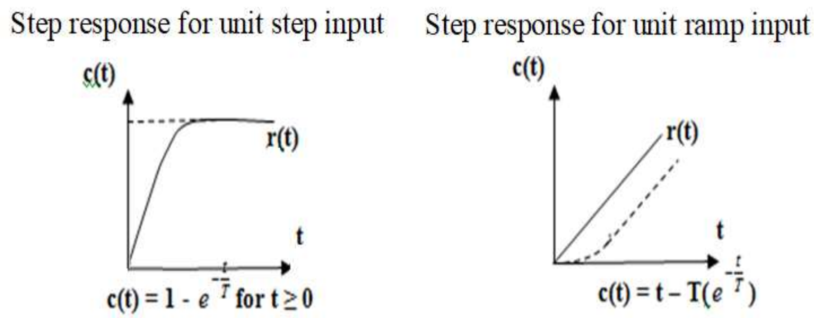
PART A

1) **Distinguish between steady state response and transient response**.

Steady state response	Transient response
The time response of the system when time tends to infinity	The time response of the system when the input changes from one state to another.
The response has settled value. It is represented by C_{ss}	The response may be exponential or oscillatory. It is represented by c(t).

2) **What are the standard test signals employed for time domain studies**? (or) **List the standard test signals used in analysis of control systems? (April 2011) (June2014) (Nov 2018)**

The standard test input signal are step input, ramp input, parabolic input and impulse input signals. By using above standard test signals of control systems, analysis and design of control systems are carried out, defining certain performance measures for the system.

<table>
<tr><td>3)</td><td>What is the initial slope of a step response of a first order system?
The step response of first order is given by $c(t) = 1 - e^{-t/T}$, where T is time constant.
The initial slope is given by,
$(dc/dt)\big|_{t=0} = (1/T)\, e^{-t/T}\big|_{t=0} = 1/T$</td></tr>
<tr><td>4)</td><td>Plot the time response of the first order system to a unit step and unit ramp input.

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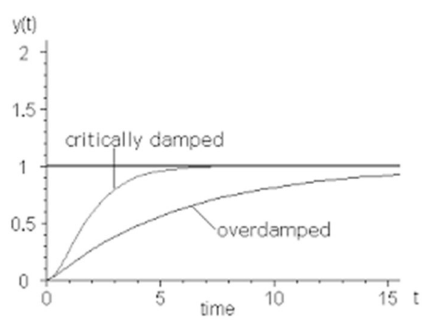
<tr><td>5)</td><td>For the system described by $\frac{C(S)}{R(S)} = \frac{16}{S^2+8S+16}$ Find the nature of time response. (Nov 2015)
In the given transfer function C(s)/R(s); the value of $\omega_n^2 = 16$ and $2\xi\omega_n = 8$
Hence the value of damping ratio $\xi = \frac{8}{2.4} = 1$
Hence the given system is a critically damped system and the step response of the system will be like:

</td></tr>
<tr><td>6)</td><td>What is the type and order of the system? (Nov2014) (May 2015) (Nov 2017)
Type – The number of poles of loop transfer function that lies at origin. The type of the system decides the steady state error.
Order- The maximum power of “s” in denominator polynomial</td></tr>
</table>

7)	**Define type and order of the following system (May 2017** $G(s)H(s) = \frac{10}{s^3(s^2+2s+1)}$ Type = 3 and Order = 5
8)	**How a control system is classified depending on the value of damping? (May2018)** ❖ Under damped system (0<ζ<1) ❖ Un damped system (ζ=0) ❖ Critically damped system (ζ=1) ❖ Over damped system (ζ>1) where ζ is damping ratio
9)	**List the time domain specifications. (May 2016)** The performance of control system in time domain is evaluated by the following specifications, Delay time(t_d), Rise time (t_r), Peak time (t_p), Peak Overshoot(M_p), Settling Time(t_s).
10)	**Define delay time and peak time**. **Delay time:** It is the time taken for response to reach 50% of the final value, for the very first time. **Peak time:** It is the time taken for the response to reach the peak value for the very first time.(or) It is the time taken for the response to reach the peak overshoot, M_p.
11)	**Define: Settling time. (Nov 2018)** It is the time required for the step response curve of under damped second order system to reach and stay within a specified tolerance band. It is usually expressed as % of final value. The usual tolerable error is 2 % or 5 % of the final value.
12)	**Define maximum peak overshoot. (May 2017)** Maximum peak overshoot is defined as the ratio of maximum peak value measured from the maximum value to final value. $\%M_p = e^{\frac{-\zeta}{\sqrt{1-\zeta^2}}\times 100}$

13)	**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, in PI control, the time taken by the controller to 'reset' the set point to bring the output to the desired value. $U(s) = K_c (1+ (1/T_i S)) E(s)$, where Ti is the integral (or) reset time.
14)	**What is steady state error? (April 2011) (May 2018)** The steady state error is the value of error signal e(t) when time (t) tends to infinity. It is a measure of system accuracy.
15)	**Distinguish between generalized error constants over static error constant**.

Static error constants	Generalized error constants
1. Do not give the information regarding the variation of error with time.	1. Gives error signal as a function of time.
2. Static error constants can be used only for standard inputs.	2. Using generalized error constant the steady state error can be determined for any type of input.
3. Give the definite values for errors, either 0 or ∞ or a finite value.	3. Give the exact error values.

16)	**Define velocity error constant.** The velocity error constant $$K_v = \lim_{s\to 0} sG(s)H(s)$$ The steady state error (e_{ss}) for type – 1 unit ramp input is given by. $\frac{1}{K_V}$
17)	**What is the positional error coefficient?** The positional error constant $$K_p = \lim_{s\to 0} G(s)H(s)$$ The steady state error (e_{ss}) for type – 0 unit step input is given by $\frac{1}{1+K_P}$

18)	**Give the relation between the static and dynamic error co-efficient. (Nov 2016)** $C_0 = \frac{1}{K_p}$ for type-0 $C_1 = \frac{1}{1+K_v}$ for type-1 $C_2 = \frac{1}{1+K_a}$ for type-2 Where C_0, C_1, C_2 are dynamic error coefficient and K_p, K_v, K_a are static error coefficients.
19)	**For servomechanism with open loop transfer function given by $G(s) = \frac{1}{(s^2+2s+3)}$. Determine the position error constant and steady sate error for a unit step input. (May 2019)** $Positional\ error\ constant\ K_p = \lim_{s \to 0} G(s)H(s) = \lim_{s \to 0} \frac{1}{(s^2+2s+3)} = \frac{1}{3}$ $Steady\ state\ error\ for\ unit\ step\ e_{ss} = \frac{1}{1+K_p} = \frac{3}{4}$
20)	**Find the steady state error of the system $G(s) = \frac{15}{s(s+8)}$ for unit ramp input. (Nov 2019)** $K_v = \lim_{s \to 0} sG(s)H(s) = \lim_{s \to 0} s \frac{15}{s(s+8)} = 1.875$ $e_{ss} = \frac{1}{K_v} = \frac{1}{1.875} = 0.533$
21)	**State the rule for finding out the root loci on the real axis.** A point on the real axis lies on the locus if the number of open loop poles plus zeros on the real axis to the right of this point is odd.
22)	**What are the applications of root locus method?** i) Root locus is used to study the dynamic response of a system ii) It visualizes the effects of varying various system parameters on root locations iii) It provides a measure of sensitivity of roots to the variation in the parameter being considered iv) It is applicable for single as well as multiple loop systems, and it helps to find the

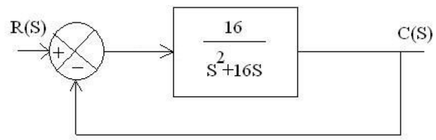
	closed loop response from the given open loop transfer function.
23)	**State the rule for finding the value of K at any point on the root locus diagram.** The value of gain K at any s = s_a on the root locus is the ratio of product of all of the vector lengths drawn from poles of G(s)H(s) to s_a and product of all of the vector lengths drawn from zeroes of G(s)H(s) to s_a.
24)	**State: Magnitude criteria in root locus approach.** The root locus magnitude criteria at any points can be defined as, $\|G(s)H(s)\| = 1$. Using this formula we can calculate the value of K at any desired point.
25)	**What is root locus? (May 2012)** It is the locus of the closed loop poles obtained when the system gain 'K' is varied from -∞ to +∞. The stability of the system is determined using this technique. The range of value of K is found such that complete performance of the system will be satisfactory and the operation is stable.
26)	**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 $= \frac{\pm 180^o (2q+1)}{n-m};\ q = 0,1,2,3,....(n-m)$
27)	**State the rule for obtaining breakaway point in root locus. (May 2011)** The break away and break in points are found from an equation for K of the characteristic's 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 breaking points, provided for this value of root, the gain K should be positive real.
28)	**What is the condition for the system G(S) = K (S + a) / S (S + b) to have a circle in its root locus? (April 2005)** If root loci is circle for the transfer function is a circle, then two poles should be located adjacently i.e b < a, where b and a are the poles and zeroes of the open loop transfer function.

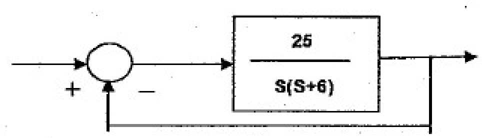
29)	**State the basic properties of root locus. (Nov 2016)** 1. The root locus is always symmetrical about the real axis. 2. If P>Z, Number of root locus branches equal to number of open loop poles. 3. If Z>P, Number of root locus branches equal to number of open loop zeroes.
30)	**Explain the function of a PID controller**. 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.e_{ss} = 0 can be achieved.
31)	**What is a derivative controller? What is its effect? (or) Why derivative controller is not used in control systems? (Nov 2015)** 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 $u(t) = k_d\, e(t)$
32)	**Write the transfer function of the PID controller. (Nov2014)** $U(s)/E(s) = K_p\,(1 + T_d s + \frac{1}{T_i s})$ Where K_p – Positional Error Constant T_i – Integral Time Constant T_d – Derivative Time Constant
33)	**What is the effect of PD controller on the system performance? (June 2014)** The PD controller introduces a zero in the system and increases damping ratio. The addition of the zero may increase the peak overshoot and reduce the rise time. But the effect of increased damping ratio ultimately reduces the peak overshoot.
34)	**What is the effect on system performance when proportional controller is introduced in the system? (Nov 2015) (Nov 2017)** A proportional controller (P controller) is a control loop feedback mechanism commonly used in industrial control systems. A P controller

	continuously calculates an error value as the difference between a desired set point and a measured process variable. The controller attempts to minimize the error over time by adjustment of a control variable. The major effect on the system performance by the Proportional controller is the offset, a constant error (permanent deviation between the set point and a measured process variable)
35)	**State the effect of PI controller on the system performance. (May 2016)(May 2019) (or) What are the feautures of PI controller (Nov 2019)** 1. Order of the system is increased by one. 2. It introduces zero in the system(Roots in the numerator). 3. The increase in order makes the system less stable than the original one. 4. Reduces the steady state error.
36)	**Discuss the effect of adding a pole to the open loop transfer function of the system?** This will reduce the steady-state error and improves steady state performance. Closer the pole towards the origin the lesser will be the steady state error. But addition of pole increases the order of the system, making the system less stable.
37)	**Discuss the effect of adding a zero to the open loop transfer function of the system? (April 2011)** The addition of a zero to open loop transfer function of a system will improve the transient response, reduces the rise time. If the zero is introduced close to origin then the peak overshoot will be larger. If the zero is introduced far away then its effect is negligible.
38)	**What is dominant pole pair? What is its significance? (April 2015) (May 2018)** The dominant pole is a pair of complex conjugate pole, which decides transient response of the system. In higher order systems the dominant poles are very close to origin and all other poles of the system are widely separated and so they have less effect on transient response of the system.
39)	**What are the effects of adding open loop poles and zero on the nature of the root locus and on system. (Nov 2017)** By addition of poles, the root locus shifts towards imaginary axis and system

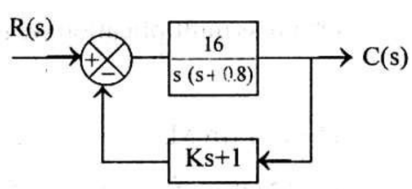
	stability decreases, while by addition of zeroes towards left half, the root locus moves away from imaginary axis and the system stability increases.
40)	**Derive the impulse response of first order system. (May 2021)** Consider the unit sample signal as an input to the first order system $$r(t) = \delta(t)$$ Apply Laplace transform on both the sides R(s)=1 Consider the first order transfer function $$\frac{C(s)}{R(s)} = \frac{1}{1+sT} \quad R(s)=1$$ $$C(s) = \frac{1}{1+sT}$$ Rearrange the above equation in one of the standard forms of Laplace transforms $$C(s) = \frac{1}{T\left(s+\frac{1}{T}\right)}$$ Apply inverse Laplace transform on both sides $$c(t) = \frac{1}{T} e^{-t/T} u(t)$$
41)	**An open loop transfer function of unity feedback system is given as $G(s) = \frac{10}{s+1}$. What is the steady state error? (May 2021)** Type 0 system $K_p = \lim_{s \to 0} G(s)\,H(s) = \lim_{s \to 0} \frac{10}{s+1} = 10$ Steady state error $$e_{ss} = \frac{1}{1+K_p} = \frac{1}{1+10} = 0.09$$
42)	**The damping ratio of a system is 0.75 and the natural frequency of oscillation is 12 rad/sec. Determine the peak overshoot and the peak time. (May 2022)** $\zeta = 0.75$ Peak Overshoot $M_p = e^{\frac{-\zeta}{\sqrt{1-\zeta^2}}} = e^{\frac{-0.75\times\pi}{\sqrt{1-0.75^2}}} = 0.028$

	$\%M_p = 2.8\%$ Damped frequency of oscillation $\omega_d = \omega_n\sqrt{1-\zeta^2} = 12\sqrt{1-0.75^2} = 7.94\,rad/sec$ Peak Time $t_d = \frac{\pi}{\omega_d} = \frac{\pi}{7.94} = 0.396se$
PART-B	
1)	(i) (a) Derive the step response of a second order under damped system **(Nov 2017)** (b) Derive the step response of a second order undamped system **(April 2011) (Nov 2014) (Nov/Dec 2015) (Nov 2018) (Nov 2019)** / Derive the time response of undamped and critically damped second order sytem for unit step input**. (May 2017) (May 2018)** (ii) Explain PID Controller action with block diagram and obtain its transfer function model**. (Nov 2015) (April 2018)**
2)	The open loop T. F of a servo system with unity feedback system is G(s) $=\frac{10}{s(0.1s+1)}$ Evaluate the static error constants of the system. Obtain the steady state error of the system, when subjected to an input given by the polynomial r(t) = a_0 + a_1t + $\frac{a_2}{2}t^2$ Also find the generalized error constants and hence e_{ss} . **(April 2014) (April 2015)**
3)	A unity feedback control system has an open loop transfer function G(s) $=\frac{5}{s(s+1)}$ Find the rise time, peak overshoot, peak time, settling time, for a step input of 10 units. Also determine the peak overshoot**. (April 2011)**
4)	A unity feedback system is characterized by an open loop transfer function G(s) $=\frac{k}{s(s+2)(s+4)}$. 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. **(April 2011) (April 2014)**
5)	Obtain the expression for dynamic error co-efficient of the following system is G(s) $=\frac{10}{s(s+1)}$ **(Nov2014)**

6)	Consider the closed loop system shown in Fig 2. Determine the range of k for which the system is stable. **(Nov 2014)** 
7)	The unity feedback system characterized by open loop transfer function G(s)=K/[s(s+10)].Determine the gain K such that the damping ratio will be 0.5 and find the time domain specifications for a unit step input**. (May 2015)**
8)	(i)The open loop transfer function of a unity feedback system is given by $G(s)=\frac{1}{S(1+S)}$. The input to the system is described by r(t)=4+6t.Find the generalized error coefficients and steady state error (ii) Explain the rules to construct root locus of a system. **(Nov/Dec 2015)**
9)	(i)The overall transfer function of the control system given by $C(s)/R(s)=16/(s^2+1.6s+16)$. It is desired that the damping ratio is 0.8. Determine the derivative rate feedback constant K_t and compare the rise time, peak time, maximum overshoot and steady state error for unit ramp input function without and with derivative feedback control. **(Nov 2016)** (ii) Compare P, I and D controllers. **(Nov 2016)**
10)	Derive the time domain specifications of a second order system. **(April 2016) /** Derive the expression for rise time and peak time of a second order underdamped system due to unit step input. **(May 2019)**
11)	(i) For a unity feedback control system, the open loop transfer function is given by $$G(s)=\frac{10(s+2)}{s^2(s+1)}$$ (a)Find the position, velocity and acceleration error co-efficient. (b) Also find the steady state error when the input is $R(S)=\frac{3}{S}-\frac{2}{S^2}+\frac{1}{3S^3}$ **(May 2016) (May 2022)** (ii) With the neat diagram explain the working of PD controller in detail. **(May 2016)**
12)	(i) A unity feedback system has open loop transfer function G(s)=K/[s(s+2)].Find

	the rise time, peak time, percentage overshoot and settling time for step input of 12 units. **(May 2017)** (ii) For servomechanism with open loop transfer function shown below explain what type of input signal give rise to a steady state error and calculate their values. **(May 2017)** (1) G(s)=[20(s+2)]/[s(s+1)(s+3)] (2) G(s)=10/[s(s+2)(s+3)]
13)	Find the static error coefficients for a system whose transfer function is $G(s)H(s)=\frac{10}{s(1+s)(1+2s)}$. And also find the steady state error. **(Nov 2017)**
14)	i) Outline the time response of first order system when it is subjected to a unit step input. **(May 2018)** ii) Determine the response of the unity feedback system whose open loop transfer function is $G(s)=\frac{4}{s(s+5)}$. **(May 2018)**
15)	For the system shown in figure below, find the rise time, peak time, peak overshoot and settling time for 2% and 4% criteria for unit step input. **(Nov 2019)** 
16)	i) A unity feedback system has the forward transfer function $G(s)=\frac{K(2s+1)}{s(5s+1)(1+s)^2}$. when the input r(t)=1+6t, determine the minimum value of K so that the steady error is less than 0.1. ii) Derive the transfer function of PID controller. **(May 2018) (Nov 2019)**
17)	A unity feedback system is characterised by the open loop transfer function $G(s)=\frac{1}{s(0.5s+1)(0.2s+1)}$. **(May 2019)** i) Write the closed loop transfer function $\frac{C(s)}{R(s)}$. ii) Calculate steady state error due to unit step input.
18)	i) A closed loop control system is represented by the differential equation

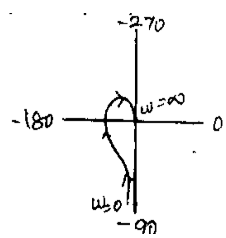
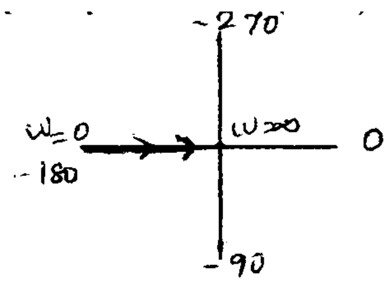
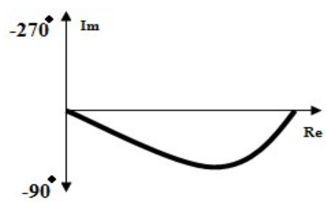
	$\frac{d^2c}{dt^2} + 4\frac{dc}{dt} = 14e$ where e = r – c is the error signal. Determine the undamped natural frequency, damping ratio and percentage maximum overshoot for a unit step input. ii) A unity feedback system is characterized by the open loop transfer function $$G(s) = \frac{1}{s(0.5s+1)(0.2s+1)}$$ Determine the steady state errors for unit-step, unit-ramp and unit-acceleration input.**(May 2021)**
19)	Sketch the root locus of the system $= \frac{k}{s(s+2)(s+4)}$ and determine the value of K such that the damping ratio of the closed loop system is 0.5**(April 2015)**
20)	Sketch the root locus for. $G(s)H(s) = \frac{k(s+2)(s+3)}{(s+1)(s-1)}$ **(Nov 2013)**
21)	Draw the root locus plot for the system whose open loop transfer function $G(s) = \frac{k}{(s+2)(s+4)(s^2+6s+25)}$. Find the marginal value of k which causes sustained oscillations and the frequency of these oscillations. **(April 2014)**
22)	Draw the root locus of the following system**. (Nov 2014)** $G(s)H(s) = \frac{k}{s(s+1)(s+2)}$. **(Or)** A unity feedback system has an open loop transfer function $G(s) = \frac{K}{s(s+1)(s+2)}$. Make a rough sketch of the root locus of the system, explicitly identifying the centroid, the asymptodes, the departure angles from the complex poles of G(s) and the jω axis crossover point. By trial and error application of the angle criterion, locate a point on the locus that gives dominant closed loop poles with ζ=0.5. Evaluate the value of K at this point. **(May 2019) (Probable Part-C)**
23)	Draw the root locus of following the system **(Nov 2016) (Probable Part-C)** $$G(S) = \frac{K(s+1)}{s(s^2+5s+20)}$$

24)	Sketch the root locus of the system having $G(s)=\frac{k(s+3)}{s(s+1)(s+2)(s+4)}$ **(May 2013) (Nov 2018) (Probable Part-C)**
25)	A unity feedback control system has an open loop transfer function. Sketch the root locus. $G(S)=\frac{K}{s(s^2+4s+13)}$. **(May2018) (Probable Part C)**
26)	Construct the root locus of the open loop transfer function (**May 2021)** $G(s)H(s)=\frac{K}{s(s+2)(s^2+2s+5)}$
27)	An unity feedback servo mechanism whose $G(S)=\frac{K_V}{s(1+sT)}$ is designed to keep a radar antenna pointed at a flying aeroplane. If the aeroplane is flying with a velocity of 600 km/h, at a range of 2 km and the maximum tracking error is to within 0.1°, determine the required velocity error coefficient K_v. (**May 2021) (Probable Part-C)**
28)	The open loop transfer function of a unity feedback system is given by G(s) = K/s(sT+1), where K and T are positive constant. Identify the amplifier gain K for reducing peak overshoot of unit step response of the system from 0.75 to 0.25. **(May2022)**
29)	A position control system with velocity feedback is shown in Fig. (i.e. G(s) = 16/s(s+0.8) and H(s) = Ks+1). Find the response c(t) to the unit step input. Given that ξ = 0.5. Also calculate rise time, peak time, maximum overshoot and settling time. **(May2022)** 
30)	Explain the step by step procedure for constructing the root locus with example. Also, show the typical sketches of root locus plots. **(May2022)**
	UNIT III FREQUENCY RESPONSE **PART A**
1)	**What is meant by frequency response? (May 2017)** The magnitude and phase function of sinusoidal transfer function of a system are

	real function of frequency ω and so they are called frequency response. The frequency response can be evaluated for open loop and closed loop system.
2)	**List any two advantages of frequency response analysis. (April 2005) (April 2011) (May 2018). Why frequency domain analysis is needed. (Nov 2018)** (a) The absolute and relative stability of the closed loop system can be estimated from the knowledge of the open loop frequency response.(b) The practical testing of system can be easily carried with available sinusoidal signal generators and precise measurement equipment. (c) The transfer function of the complicated functions can be determined experimentally by frequency response tests.(d) The design and parameter adjustments can be carried more easily.(e)The corrective measure for noise disturbance and parameter variation can be easily carried.(f)It can be extended to certain non - linear systems
3)	**What are frequency domain specifications? List it out. (Nov 2017)** The frequency domain specifications indicate the performance of the system in frequency domain; they are resonant peak, resonant frequency, Band width, Phase margin, Gain margin
4)	**Define resonant peak and resonant frequency (June 2014) (Nov 2014)** **Resonant peak:** 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. **Resonant frequency:** 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, $\omega_r = \omega_n \sqrt{1-2\xi^2}$
5)	**The damping ratio and natural frequency of oscillations of a second order system is 0.3 and 3 rad/sec respectively. Calculate resonant frequency and resonant peak. (May 2019) (May 2022)** Resonant frequency $\omega_r = \omega_n\sqrt{1-2\zeta^2} = 3\sqrt{1-2\times 0.3^2} = 2.71\ rad/sec$ Resonant Peak $M_r = \dfrac{1}{2\zeta\sqrt{1-\zeta^2}} == \dfrac{1}{2\times 0.3\sqrt{1-0.3^2}} = 0.57$

6)	**Define the term Gain Margin. (Nov 2014) (May 2021) (May 2022)** The gain margin is the factor by which the system gain can be increased to drive it to the verge of instability. It may be defined as the reciprocal of the gain at the phase cross over frequency (ω_{pc}). 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 $Kg\,in\,db = 20\log Kg = 20\log\frac{1}{\lvert G(j\omega_{pc})\rvert}$
7)	**Define phase margin. (April 2004) (Nov 2014) (May 2015) (May 2018) (May 2021)** 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 $\phi_{gc} = \angle G(j\omega) H(j\omega)$ at $\omega = \omega_{gc}$
8)	**Define Gain Crossover Frequency. (April 2011) (May 2016)(Nov 2019)** The gain crossover frequency is the frequency at which the magnitude of open loop transfer function is unity. It is represented by ω_{gc}.
9)	**Define phase cross over frequency. (May 2016)** The phase cross over frequency is the frequency at which the phase of open loop transfer function is 180°. It is represented by ω_{pc}.
10)	**Obtain the corner frequencies of the system G(s)H(s) = (s+0.5)/(s+0.25) (s+4)** Corner frequency for the polynomial (1+sT) is 1/T Corner frequency for the polynomial (s+0.5) is 0.5 Corner frequency for the polynomial (s+0.25) is 0.25 Corner frequency for the polynomial (s+4) is 4
11)	**What is meant by the term 'corner frequency'? (May 2018)** Asymptotic straight lines can approximate the magnitude plot. The frequencies corresponding to the meeting point of asymptotes are called corner frequencies. The slope of the magnitude plot changes at every corner frequency.

12)	**What is bode plot? State the advantage of Bode plot.** The bode plot is a frequency response plot of the transfer function of a system. It consists of two plots, magnitude plot and phase plot. Magnitude plot: Plot between magnitude in db and logω for various values of ω. Phase plot: Plot between phase in degrees and logω 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: (a) The approximate plot can be sketched quickly, (b) The frequency domain specifications can be easily determined; (c) The Bode plot can be used to analyze both open loop and closed loop system.
13)	**What is approximate bode plot.** In approximate bode plot, the magnitude plot of first and second order factors are approximated by two straight lines, which are asymptodes to exact plot. One straight line is at 0dB, for the frequency range of 0 to ω_c and other straight line is drawn with a slope of $\pm$20n db/sec for the frequency range ω_c to ∞ .
14)	**If the bode plot crosses 180° line, either at very low frequencies or very high frequencies in the selected frequency range. What is the inference regarding the relationship between open loop gain and stability? (May 2019)** It is an indication that the closed loop response will be either absolutely stable or unstable, irrespective of the value of the open loop gain. So even if the phase line just grazes the 180° line without crossing it, it can be taken as phase crossover frequency ω_{pc} using which gain margin can determine.
15)	**What does a gain margin close to unity and phase margin close to zero indicate? (Nov 2016)** The gain margin close to unity and phase margin close to zero indicate that the system is relatively stable
16)	**Why is frequency domain compensation normally carried using the bode plots? (Nov 2016)** The frequency domain compensation may be carried out by using Nyquist plots, bode plots and Nicholas charts. Out of them normally bode plots are preferred,

	because they are easier to draw and modify. Also, the gain adjustments can be carried out and also the error constants are always clearly in evidence in the bode plots.
17)	**Show the shape of the polar plot for the transfer function K/s $(1 + sT_1)(1 + sT_2)$ (Nov 2018)** 
18)	**Sketch the polar plot of $10/s^2$ (or) draw the approximate polar plot for type 0 second order system. (Dec 2015)** 
19)	**Sketch the polar plot for G(s)=1/1+sT (April 2015)** In the given transfer function, the type of the system is zero and the order is 1. So, the model polar graph will be like: 
20)	**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. The minimum phase systems are systems with minimum phase transfer functions.

21)	**What are all pass systems and non-minimum phase transfer function?** All pass systems: The magnitude is unity at all frequencies and the transfer function will have anti symmetric pole zero pattern (i.e. for every pole in the left half 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.
22)	**What are M and N circles.** The magnitude, M of closed loop transfer function with unity feedback will be in the form of circle in complex plan for each constant value of M. The families of these circles are called M circles. Let N=tanα, where α is the phase of closed loop transfer function with unity feedback. For each constant value of N, a circle can be drawn in the complex plan. The family of these circles are called N-circles.
23)	**How the closed loop frequency response is determined from the open loop frequency response using Nichols chart.** The G(jω) locus or the Nichols plot is sketched on the standard Nichols chart. The meeting point of M-contour with G(jω) locus gives the magnitude of closed loop system and the meeting point with N-circle gives the argument/phase of the closed loop system.
24)	**What is the phase shift contributed by single pole at origin in a transfer function.** The phase shift contributed by single pole at origin in a transfer function is -90°.
25)	**Find the type and order of the system $G(s) = \frac{10}{s^2(s+1)(s+2)}$ (May 2021)** Type : 2, Order: 4
	PART B
1)	Derive the expression for the frequency domain specifications. **(Nov 2018)**
2)	Explain how open loop response can be obtained from closed loop response. **(Nov 2018)**
3)	Sketch the polar plot of $G(s) = \frac{1}{[s(1+0.5s)(1+0.02s)]}$ and determine the phase cross

	over frequency. **(May 2022)**
4)	Given $G(s) = \frac{Ke^{-0.2s}}{[s(s+2)(s+8)]}$. Find K so that the system is stable with Gain margin equal to 6 db and (b) Phase margin equal to 45^0 using bode plots. **(Probable Part-C)**
5)	Sketch the Bode plot for the following transfer function and obtain gain and phase cross over frequencies. $G(s) = \frac{20}{[s(1+0.4s)(0.1s+1)]}$ **(April 2011)**
6)	The open loop transfer function of a unity feedback system is given by $G(s) = \frac{1}{[s^2(1+s)(1+2s)]}$ Sketch the polar plot and determine the phase margin and gain margin**. (April 2011) (April 2015)**
7)	Sketch the Bode plot showing the magnitude in db and phase angle in degrees as a function of log frequencies for the following transfer function $G(s) = \frac{75(1+0.2s)}{[s(s^2+16s+100)]}$ and obtain gain and phase cross over frequencies. **(April 2014) (April 2018) (May 2022)**
8)	(i)Discuss the correlation between the time and frequency response of second order system. **(April 2014) (Nov 2015) (Nov 2018)** **(**ii) Explain the use of nichol's chart to obtain closed loop frequency response from open loop frequency response of unity feedback system **(Nov/Dec 2015)**
9)	Using Bode plot of the following system $G(s) = \frac{10}{[s(.1s+1)(0.01s+1)]}$ and Hence obtain the gain crossover frequency**. (Nov 2014)**
10)	Using polar plot determine the gain cross over frequency, phase cross over frequency, gain margin, phase margin feedback system with open loop transfer function $G(s) = \frac{1}{[s\ \ (1+0.2s)(1+.002s)]}$**. (Nov 2014)**
11)	Sketch the Bode plot for the following transfer function and obtain gain and phase cross over frequencies. $G(s) = \frac{10}{[s(1+0.4s)(0.1s+1)]}$ **(April 2015) (May 2016) (May 2017)**

12)	Sketch the Bode plot for the following transfer function and obtain gain and phase margin and closed loop system stability. $G(s)=\dfrac{4}{[s(1+0.5s)(0.08s+1)]}$ **(Nov 2015)**
13)	The open loop transfer function of the unity feedback system is given by $G(S)=\frac{1}{S(S+1)^2}$ Sketch the polar plot and determine the gain and phase margin. **(May 2016)(May 2021)**
14)	Sketch the polar plot of $G(s)=\dfrac{1}{[s(1+s)(1+2s)]}$ and determine the phase margin and gain margin. (**Nov 2016) (May 2017)**
15)	Sketch the Bode plot for the following transfer function $G(s)=\dfrac{1}{[s(s^2+3s+5)]}$ and obtain gain and phase margin. (**Nov 2016)**
16)	Sketch the bode plot and hence find gain cross over frequency, phase cross over frequency, gain margin and phase margin for the function. (**Nov/Dec 2017)** $G(s)=\dfrac{10(s+3)}{s(s+2)(s^2+4s+100)}$.
17)	Sketch the polar plot for the following transfer function and find gain cross over frequency, phase cross over frequency, gain margin and phase margin for $G(s)=\dfrac{400}{s(s+2)(s+10)}$.(**Nov 2017)**
18)	Construct the polar plot and determine the gain and phase margin of a unity feedback control system whose open loop transfer function is, $G(s)=\dfrac{(1+0.2s)(1+0.025s)}{s^3(1+005s)(1+0.001s)}$ **(May 2018)**
19)	Sketch the Bode plot for the following transfer function and obtain gain and phase margin and closed loop system stability. $G(s)=\dfrac{100}{s(s+1)(s+2)}$ **(May 2019).**
20)	Sketch the polar plot for the following open loop transfer function and determine the gain margin and phase margin $G(s)=\dfrac{1}{(1+s)(1+2s)}$ **.(May 2019)**

21)	Draw the bode plot for the transfer function $H(s) = \dfrac{100(s+1)}{(s+10)(s+100)}$ **(Nov 2019)**
22)	Compare polar plots of type 0, type 1 and type 2 systems. **(Nov 2019)**
23)	Sketch the Bode plot for the given transfer function. Determine Gain cross-over frequency phase cross-over frequency, gain margin and phase margin **(May 2021)** $$G(s)H(s) = \frac{2000}{s(s+2)(s+100)}$$

UNIT IV – STABILITY AND COMPENSATION

PART A

1)	**Define asymptotic stability. (April 2004) (Nov 2018)** 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.
2)	**State the necessary condition for the Routh's criterion for stability. (April 2015)/ What ate the necessary condition for stability. (Nov 2017) (May 2022)** A necessary and 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.
3)	**The characteristic equation of a feed back control system is $s^4 + 22 s^3 + 10s^2 + 32 s + K = 0$. Determine the range of K for which the system is stable.** S^4 1 10 K S^3 22 32 0 S^2 8.545 K 0 S^1 $\dfrac{(273.45-22K)}{8.545}$ 0 S^0 K 0 For the system to be stable all the first column elements should be positive. K> 0 and 273.45-22K > 0, 273.45> 22K, K< 12.43 When 0<K<12.43 the system is stable.

4) **What are the characteristics of an unstable system? (Nov 2004)**

The system will give unbounded output for a bounded input, the system has roots with positive real part, the system has repeated roots on $j\omega$ axis.

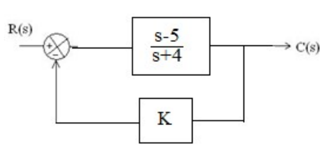
5) **Distinguish between relative stability and absolute stability.**

Relative stability	**Absolute stability**
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.
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.

6) **What is meant by characteristic equation? What is its significance? (May 2016) (May 2017)**

The denominator polynomial of closed loop transfer function equated to zero is the characteristic equation. It tells about the stability of the system.

7) **For what range of K the following system shown below is asymptotically stable. (May 2019)**



Characteristic equation is given by

1+G(s)H(s) = 0

$$1+\frac{K(s-5)}{s+4}=0$$

(K+1) s-5K+4=0

Using Routh Hurwitz criterion,

s^1	K+1	0
s^0	4-5K	

For marginal stability,

	K+1>0 4-5K>0 Hence range of K is -1<K<4/5
8)	**How are the locations of roots of characteristic equation related? (or) How are the roots of characteristic equation related to the stability of system (June 2014) (Nov 2015)** 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 unstable. d)If the characteristic equation has non-repeated roots on the jω axis the system is limitedly Stable.
9)	**What are compensators? (Nov 2014)** In control systems design, under certain circumstances it is necessary to introduce some kind of corrective subsystems to force the chosen plant to meet the given specifications. These subsystems are known as compensators and their job is to compensate for the deficiency in the performance of the plant.
10)	**Why compensation is necessary in feedback control systems? (April 2011) (June 2014) (April 2015) (May 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, then compensation is required to meet the desired performance.
11)	**What is lag compensator? Give an example?** A compensator having the characteristics of a lag network is called lag compensator. If a sinusoidal signal is applied then in steady state output there will be a phase lag with respect to input. E.g. R-C network.

12)	**What is lead compensator? Give an example?** A compensator having the characteristics of a lead network is called a lead compensator. It gives a phase lead with respect to input if applied with sinusoidal signal. A R- C network can realize it.
13)	**What is the basis for selection of particular compensator for a system? (Nov 2015)** When transient response needs is to improved, a lead compensator is chosen.When staedy state response is to be improved, while nearly preserving the transient response, a lag compensator is chosen.When both the transient and steady state response are to be improved, a lag lead compensator is chosen,
14)	**What is lag-lead compensator. (May 2016) (May 2017)** 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 occur 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.
15)	**Give the need for lag/lag-lead compensation. (Nov 2017)** Phase lag network allows low frequencies and high frequencies are attenuated. It provides high steady state accuracy. Lag-lead compensator provides high steady state accuracy and speed of response.
16)	**State the property of a lead compensator. (Nov 2013)** 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.

17) Write the transfer function of a typical lag lead compensator. (April 2005) (June 2014)

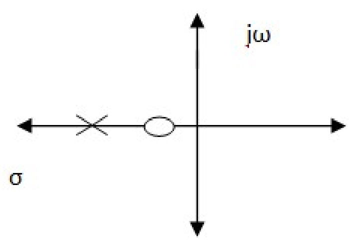
$$G(s)=\left(\frac{s+\frac{1}{\tau_1}}{s+\frac{1}{\beta\tau_1}}\right)\left(\frac{s+\frac{1}{\tau_2}}{s+\frac{1}{\alpha\tau_2}}\right)$$

The lag section has pole at s = $-1/\beta\ \tau_1$ and a zero at s = $-1/\tau_1$. The lead section has pole at s = $-1/\alpha\ \tau_1$ and a zero at s = $-1/\tau_2$

18) Write the transfer function of a typical lead compensator and draw its pole-zero plot (April 2011)

$$G(s)=\left(\frac{s+\frac{1}{\tau}}{s+\frac{1}{\alpha\tau}}\right)$$

Pole zero plot:



19) Draw the circuit of lead compensator and draw its pole zero diagram. (May 2011) (Nov 2018)

The lead compensator has a pole at $s=-\dfrac{1}{\alpha T}$ and a zero at $s=-\dfrac{1}{T}$.

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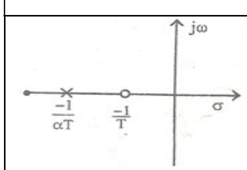
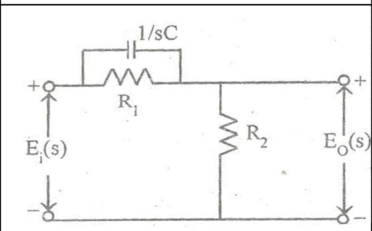
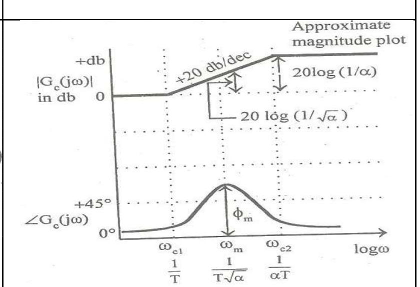
<tr><th>Pole-zero diagram</th><th>Electrical circuit</th><th>Bode plot</th></tr>
<tr><td>
</td><td>
</td><td>
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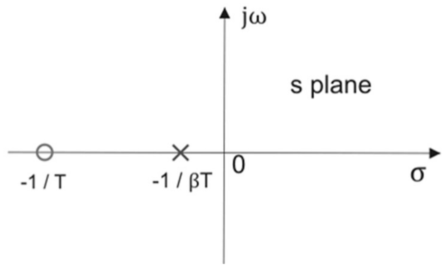
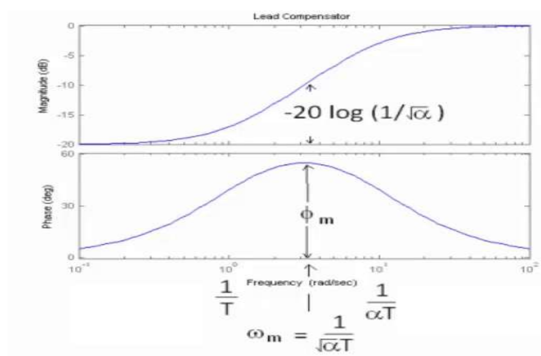
20)	**What are the effects and limitations of phase lag control? (Nov 2016)** (i)For a given forward path gain, K the magnitude of forward path transfer function is attenuated near the above the gain cross over frequency, thus improving the relative stability of the system. (ii)The gain cross over frequency is decreased and thus the bandwidth of the system is reduced. (iii)The rise time nad settling time of the system are usually longer, because the bandwidth is usually decreased. (iv)The system is more sensitive to the parameter variations because the sensitivity function is greater than unity for all frequencies approximately greater than bandwidth of the system.
21)	**State Nyquist stability criterion. (May 2012) (May 2013) (June 2014) (May 2016) (May 2017)(May 2021) (or) What is the condition for stability of a closed loop system according to Nyquist stability criterion. (Nov 2019).** 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 halves of s-plane poles of G(s)H(s). Then the closed loop system is stable.
22)	**Write the transfer function of lag compensator and draw its pole-zero diagram (or) draw the electrical lag network and draw its pole-zero plot. (April 2015) (Nov 2015)** A system which has one zero and one dominating pole (the pole which is closer to origin that all other poles is known as dominating pole) is known as lag network. The basic requirement of the lag network is that all poles & zeros of the transfer function of the network must lie in (-) ve real axis interlacing each other with a pole located or on the nearest to the origin. $G(s) = \left(\frac{1+Ts}{1+\beta Ts} \right)$ The above network provides a high frequency gain of $1/\beta$



23) **What are the two notions of system stability to be satisfied for a linear time invariant system to be stable? (Nov 2016)**

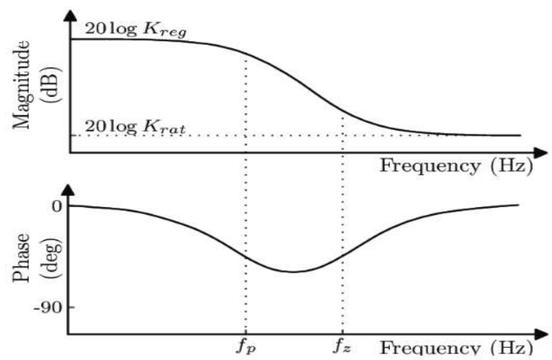
The two notions of system stability to be satisfied for a linear time invariant system to be stable are (i)When the system is excited by a bounded input, the output is bounded.(ii) In the absence of the input, the output tends to zero irrespective of initial conditions.

24) **Draw the frequency response of lead compensator. (Nov 2019)**



25) **Compare lag compensator with lead compensator. (May 2021)**

Lag compensator	Lead compensator
Lag compensator is a basically low pass filter	Lead compensator is a basically high pass filter
Lag compensator improves the steady state performance, reduce the bandwidth and increases the rise time	Lead compensator increases the bandwidth, improves the speed of response and reduces the peak overshoot
When the system is stable and does not satisfy the steady state performance	When the system is stable or unstable and requires to improvement in

	specifications then lag compensation is employed | transient state response then lead compensator is employed
26)	Draw the Bode plot of lag compensator. **(May 2022)** 
	PART B
1)	Construct the Routh array and determine the stability of the system represented by the characteristic equation $s^5+s^4+4s^3+24s^2+3s+63=0$. Comment on the location of the roots of characteristic equation **(April 2011)**
2)	The characteristic equation of a feedback control system is given by $s^4+20s^3+15s^2+25+K=0$. Determine the value of K which will cause sustained oscillations in the closed loop system. What are the corresponding oscillating frequencies? **(April 2011)**
3)	(i)The open loop transfer function of a unity feedback control system is given by $G(S)=\frac{K}{[(s+2)(s+4)(s^2+6s+25)]}$ By applying Routh criterion discuss the stability of the closed system as a function of K. Determine the values of K which will cause sustained oscillations in the closed loop system. What are the corresponding frequencies? **(April 2014) (Nov 2015)**
4)	Determine the stability of the given characteristic equation using Routh-Hurwitz criterion (a) $s^5+4s^4+8s^3+8s^2+7s+4=0$**(May 2016) (May 2019)** (b) $s^6+s^5+3s^4+3s^3+3s^2+2s+1=0$ **(April 2015)**
5)	Find the stability of the system with characteristic equation $2s^4+s^3+8s^2+s+1=0$

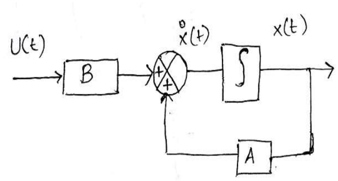
	using Routh Hurwitz Stability criteria, state its advantages and limitations. **(Nov 2019)**
6)	Determine the value of K for which the system describes by the following characteristics equation is stable $S^3+KS^2+(K+2)S+4=0$ **(Nov 2016)**
7)	Using Routh Hurwitz criterion, determine the stability of a system representing the characteristic equation $s^4+8s^3+18s^2+16s+5=0$. Comment on the location of roots of the characteristic equation. **(May 2017)**
8)	A unity feedback control system is characterized by the open loop transfer $G(s).=\frac{K(s+13)}{s(s+3)(s+7)}$. Using Routh criterion, calculate the range of values of K for the system to be stable. Also determine the value of K the system become marginally stable and calculate the frequency of oscillation if any. **(May 2021)**
9)	Explain in detail the design procedure of lag–lead compensator using Bode plot. **(May 2013) (April 2015)**
10)	(i) Explain in detail the design procedure of lag compensator using Bode plot. **(April 2014) (April 2015) (May 2016)(May 2017)** (ii) Derive the transfer function of lag-lead compensator. **(Nov 2015)**
11)	Explain the electric network realization of lead compensator and also its frequency response characteristics. **(April 2014)**
12)	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 K_v = 10 sec^{-1}, phase margin = 50° and gain margin ≥ 10db. **(May 2011)(Nov 2018)**
13)	A unity feedback control system has an open loop transfer function G(s)= $\frac{5}{[s(s+1)(0.5s+1)]}$ Design a suitable compensator such to maintain Phase margin of at least 40°**.(Nov 2014)**
14)	Explain in detail the realization of lag, lead and lag-lead electrical network. **(May 2017)**
15)	Explain in detail the design procedure of lead compensator using Bode plot. **(Nov**

	2015) (May 2022)
16)	Design a lead compensator for a unity feedback control system has an open loop transfer function G(s)=$\frac{k}{[s(s+1)]}$ for the specifications of K_V=10sec^{-1} and phase margin is 35°. **(Nov 2016) (Probable Part-C)**
17)	Consider the unity feedback whose open loop transfer function is $$G(s) = \frac{K}{S(0.1s+1)(0.2s+1)}$$ System to be compensated to meet the following specifications: Static velocity error constant = 30 /sec, Phase margin ≥50-degree, Bandwidth (ω_b) = 12 rad/sec. **(Nov 2018) (Probable Part-C)**
18)	Consider the unity feedback whose open loop transfer function is G(s)= $\frac{K}{[s(0.1s+1)(0.2s+1)]}$ system to be compensated to meet the following specifications Static velocity error constant = 30 sec, Phase margin ≥ 50°,Bandwidth ω_1=12 rad/ sec. **(Nov 2014) (Probable Part-C)**
19)	For the given system, $G(s)=\frac{K}{s(s+1)(s+2)}$, design a suitable lag-lead compensator to give velocity error constant =10sec^{-1}, phase margin=50^o, gain margin≥10dB. Realize the basic compensators using electrical network and obtain the transfer function. **(Nov 2017) (Probable Part-C)**
20)	Design a lead compensator for unity feedback system whose open loop transfer function $G(s) = \frac{K}{S(s+1)(s+5)}$ to satisfy the following condition i) Velocity error constant Kv≥50 ii) Phase margin ≥20 degrees. **(May 2018) (Probable Part-C)**
21)	Design a lag compensator for the system $G(s) = \frac{K}{S(s+2)}$ to satisfy the following specifications: (i) Static velocity error constant Kv =10 sec^{-1}, (ii). Phase margin ϕ_m ≥60^o. **(May 2019) (Probable Part-C)**
22)	Design a lag compensator for the system to have a phase margin of 65 degrees $$G(s) = \frac{1}{(S+1)(0.25s+1)}$$

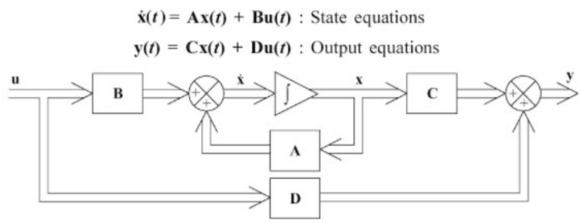
	H(s)=1, Maximum steady state error for unit step input =0.1. **(Nov 2019)**
23)	Sketch the Nyquist plot for the system whose open loop transfer function. G(s) H(s) = $\frac{K}{[s(s+2)(s+10)]}$ And find the range of K for stability of closed loop. **(May 2016) (Probable Part-C)**
24)	By use of Nyquist stability criterion determine whether the closed loop system having the following open loop transfer function is stable or not .If not how many closed loop poles lies in the right half s-plane G(s)H(s)= $\frac{(s+2)}{[(s+1)(s-1)]}$ **(Nov/Dec 2015) (Nov 2019)(Nov 2017)**
25)	Construct the Nyquist plot for a system whose open loop transfer function is given by $G(s)=\frac{K(1+s)^2}{s^3}$, find the range of K for stability. **(May 2018) (Probable Part-C)**
26)	Sketch the Nyquist plot for the system whose open loop transfer function. G(s) H(s) = $\frac{K(s+2)}{[s(s+3)(s+6)]}$. And find the range of K for stability of closed loop. Check your answer with Routh's criterion. **(Nov 2018)**
27)	Determine the stability of closed loop system by Nyquist stability criterion, whose open loop transfer function is given by, $G(s).H(s)=\frac{(s+4)}{(s+1)(s-1)}$. **(May 2021)**
28)	Construct the Routh array and determine the stability of the systemrepresented by the characteristics equation $s^5+s^4+2s^3+2s^2+3s+5 = 0$. Comment on the location of the roots of characteristics equation. **(May 2022)**
UNIT V STATE VARIABLE ANALYSIS **PART A**	
1)	**What are the advantages of state space analysis? (Nov 2011) (May 2013) (May 2018) (May 2019)(May 2021)** 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.
2)	**What is state space? (May 2016)** The set of all possible values which the state vector X(t) can have at time 't' forms the state space of the system.
3)	**Define state and state variable. (Nov 2012) (May 2013) (Nov 2015)** State: the state is the condition of a system at any time instant. State variable: a set of variables which describe the state of the system at any time instant are called state variables.
4)	**What are phase variables?** The phase variables are defined as those particular state variables which are obtained from one of the system variable and its derivatives. Usually the variable used is the system output and the remaining state variable and then derivatives of the output.
5)	**Write the properties of state transition matrix. (May 2010) (May 2014)** 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. $\phi(t_1 + t_2) = e^{A(t_1+t_2)} = e^{At_1}\,e^{At_2} = \phi(t_1)\phi(t_2) = \phi(t_2)\phi(t_1)$
6)	**Define: State equation. (Nov2013)** The state variable model can be represented in the form of n first order differential equations as $\frac{dX_1}{dt} = \dot{X}_1(t) = A_{11}X_1(t) + A_{12}X_2(t) +, \ldots\ldots + A_{1n}X_n(t) + B_1u(t)$ $\frac{dX_2}{dt} = \dot{X}_2(t) = A_{21}X_1(t) + A_{22}X_2(t) +, \ldots\ldots + A_{2n}X_n(t) + B_2u(t)$: : $\frac{dX_n}{dt} = \dot{X}_n(t) = A_{n1}X_1(t) + A_{n2}X_2(t) +, \ldots\ldots + A_{nn}X_n(t) + B_nu(t)$ These equations are called state equations

7)	**What is state diagram? What are the basic elements used to construct the state diagram.** The pictorial representation of the state model of a system is called state diagram. The state diagram of the system can be either in block diagram or in a signal flow graph form. The basic elements used to construct the state diagram are scalar, adder and integrator.
8)	**What are the advantages of state space modelling using physical variables?** (a)The state variable can be utilized for the purpose of feedback (b)The implementation of design with state variable feedback becomes straight forward (c) The solution of state equation gives time variation of variables which have direct relevance to the physical system.
9)	**What is the advantage and disadvantage in canonical form of state model.** The advantage of canonical form is that the state equation are independent of each other. The disadvantage is that the canonical variables are not physical variables and so they are not available for measurement and control.
10)	**Write the solution for homogenous state equations.** The solution of homogenous state equation is $X(t) = e^{At} X_0$ where $X(t)$ = State vector at time time, t e^{At} = State transition matrix X_0 = Initial condition vector at t=0
11)	**What is resolvant matrix.** The laplace transform of state transition matrix is called resolvant matrix. Resolvant matrix $\phi(s) = £[\phi(t)] = £[e^{At}]$ Also $\phi(s) = [SI-A]^{-1}$
12)	**How the model matrix is determined? (May 2012)** The model matrix M can be formed from eigenvectors. Let $m_1, m_2, m_3,....m_n$ 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 = $[m_1\ m_2\ m_3\ ,....\ m_n]$

13)	**Give the concept of controllability. (Nov 2013) (Nov 2015) (May 2017)** 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.
14)	**When a system is said to be completely observable? (May 2016)** 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.
15)	**State the concept of observability? (May 2018) (Nov 2018) (May 2022)** The observability test is necessary to find weather the state variables are 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.
16)	**What is the necessary condition for complete Observability of a system? (Nov 2019)** For a nth order system described by state model $\dot{X} = AX + BU$ $Y = CX + DU$ We can form a composite matrix Q_0 where $Q_0 = [C^T \;\; A^T C^T \;\; (A^T)^2 C^T \;\; (A^T)^3 C^T \ldots\ldots (A^T)^{n-1} C^T \;]$ If the system is completely observable if the rank of composite matrix Q_0 is n.
17)	**State the limitations of state variable feedback. (Nov 2016)** The limitations of state variable feedback are more states are to be known. These states can either measured or estimated. This technique is insensitive to system parameter changes and external disturbances.
18)	**For a first order differential equation described by $\dot{X}$=Ax(t)+bu(t). Draw the block diagram form of the state diagram. (Nov 2016).** 

19) **Draw the block diagram representation of state model. (May 2017)**



20) **State the mechanism in control engineering which implies an ability to measure the stable by taking measurement at output. (May 2019)**

Observability and Controllability are the two methods to check the output response characteristics and observability in control engineering implies an ability to measure the stable by taking measurement at output.

21) **Find the controllability matrix for the system**

$$\begin{bmatrix} \dot{x}_{1r} \\ \dot{x}_{2r} \end{bmatrix} = \begin{bmatrix} -2 & -3 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} x_{1r} \\ x_{2r} \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$$

$$y = [0 \;\; 1] \begin{bmatrix} x_{1r} \\ x_{2r} \end{bmatrix}$$

$$Q_c = [B \quad AB] = \begin{bmatrix} 1 & -2 \\ 0 & 1 \end{bmatrix} = 1 \neq 0$$

The rank of Q_c is 2

The system is completely controllable.

22) **Write the state model of a linear time invariant system.(May 2021)**

The state model of a linear time invariant system is given by

$$\dot{X} = AX + BU$$

$$Y = CX + DU$$

$\dot{X}$- Differential state vector

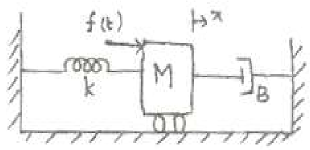
Y – Output vector ,U – Input vector, A – State matrix, B – Input matrix, C – Output matrix, D – Transition matrix

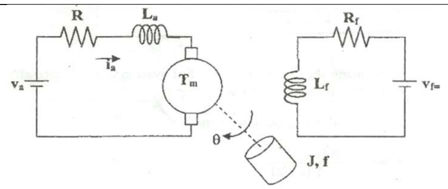
23) **List the merits and demerits of phase variables. (May 2022)**

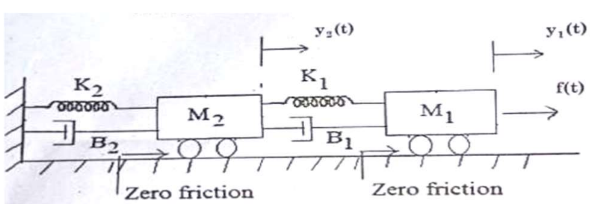
Merits:

Using phase variables, the system state model can be written directly by inspection from differential equation governing the system.

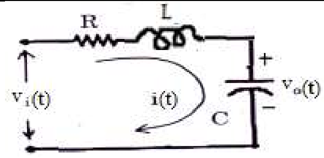
The phase variables provide a link between the transfer function design approach

	and time domain design approach. **Demerits:** The disadvantages in choosing phase variables is that the phase variables are not physical variables of the system and therefore are not available for measurement and control process
PART – B	
1)	The state space representation of a system is given below. Obtain the transfer function. **(May 2011)** $\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix} = \begin{bmatrix}-2 & 1 & 0\\ 0 & -3 & 1\\ -3 & -4 & -5\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix} + \begin{bmatrix}0\\ 0\\ 1\end{bmatrix}u \quad y = \begin{bmatrix}0 & 1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}$
2)	(i) Find the state variable equation for a mechanical system (spring-mass-damper system) shown below. (**Nov 2011)**  (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 $x_0 = \begin{bmatrix}1\\ 0\end{bmatrix}$
3)	Obtain the time response of the system described by $\dot{x}(t)=\begin{bmatrix}0 & 1\\ -1 & -2\end{bmatrix}\begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix}+\begin{bmatrix}1\\ -1\end{bmatrix}U(t)$ With the initial conditions $\begin{bmatrix}x_1(0)\\ x_2(0)\end{bmatrix}=\begin{bmatrix}0\\ 1\end{bmatrix}$; y(t)=$\begin{bmatrix}0 & 1\end{bmatrix}\begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix}$.**(Nov 2016)**
4)	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) /** Determine and show the state model of armature-controlled DC motor with neat sketch. **(May 2022)**
5)	(i) The state model matrices of a system are given below. Evaluate the observability of the system using Gilbert's test. **(May 2012)** $A=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & -1\\ 0 & -2 & -3\end{bmatrix}, B=\begin{bmatrix}0\\0\\1\end{bmatrix}\ and\ C=\begin{bmatrix}3 & 4 & 1\end{bmatrix}.$ (ii) Find the controllability of the system described by the following equation. $\dot{X}=\begin{bmatrix}-1 & -1\\ 2 & -1\end{bmatrix}\begin{bmatrix}X_1\\X_1\end{bmatrix}+\begin{bmatrix}0\\1\end{bmatrix}U(t)$
6)	A system is represented by the state equation X=AX+BU; Y=CX where $A=\begin{bmatrix}0 & 1 & 0\\ 0 & -1 & 1\\ 0 & -1 & -10\end{bmatrix}, B=\begin{bmatrix}0\\0\\10\end{bmatrix}\ and\ C=[100].$ Determine the transfer function of the system. **(May 2013)**
7)	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)**
8)	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. $\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix}=\begin{bmatrix}0 & 1\\ -2 & -3\end{bmatrix}\begin{bmatrix}x_1\\x_2\end{bmatrix}+\begin{bmatrix}0\\2\end{bmatrix}[u]\ \begin{bmatrix}x_1 & 0\\ x_2 & 0\end{bmatrix}=\begin{bmatrix}0\\1\end{bmatrix}$ **(Nov 2013)**
9)	Consider the system with the state equation. Check the controllability of the

	system. **(Nov 2013)** $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$
10)	(i) Obtain the state model of the system described by the following transfer function. $\frac{y(s)}{u(s)} = \frac{5}{s^2+6s+7}$. (ii) Obtain the state transition matrix for the state model whose system matrix A is given by $A = \begin{bmatrix} 1 & 1 \\ 0 & 0 \end{bmatrix}$ **(May 2014)**
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. $A=\begin{bmatrix} 0 & 1 \\ -6 & -5 \end{bmatrix}$ $B=\begin{bmatrix} 1 \\ 0 \end{bmatrix}$ $C=\begin{bmatrix} 1 & 0 \end{bmatrix}$ $D=\begin{bmatrix} 0 \end{bmatrix}$
12)	Consider the system with the state equation. Check the controllability and observability of the system. **(Nov 2015) (May 2016)** $A=\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}$, $B=\begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$ $C^T=\begin{bmatrix} 10 \\ 5 \\ 1 \end{bmatrix}$
13)	(i) Obtain the state model of the system **(Nov 2015)**  (ii) State and prove the properties of state transition matrix (**Nov 2015)**
14)	(i) The state model of the system is defined by $\dot{x}(t)$=Ax(t)+bu(t), y(t)=CX(t) where

	A= $\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}$, B= $\begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$, C = [1 0 0]. Obtain the diagonal canonical form of the state model by the suitable transformation matrix. **(May 2016)** (ii) Explain about the effect of state feedback**. (May 2016)**
15)	Determine whether the system described by the following state model is completely controllable and observable **(Nov 2016)** $\dot{x}$ (t) = $\begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}+\begin{bmatrix} 0 \\ 2 \\ 0 \end{bmatrix}$ u(t); Y(t)=[1 0 0] $\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$
16)	Check the controllability and observability of the system whose state space representation is given as **(May 2017)** $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \\ 1 & -2 & 0 \\ 2 & 1 & -3 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 10 \\ 1 \\ 0 \end{bmatrix} u \quad y = [1 \;\; 0 \;\; 0] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$
17)	(i) What are state variables. Explain the state formulation with its equation. **(May 2017)** (ii) Given that **(May/June 2017)** $\mathbf{A_1} = \begin{bmatrix} \sigma & 0 \\ 0 & \sigma \end{bmatrix} \mathbf{A_2} = \begin{bmatrix} 0 & \omega \\ -\omega & 0 \end{bmatrix} \quad \mathbf{A_3} = \begin{bmatrix} \sigma & \omega \\ -\omega & \sigma \end{bmatrix}$ Compute state transition matrix.
18)	Explain the concepts of controllability and observability. **(Nov 2017)**
19)	Determine the canonical state model of the system whose transfer function is $T(s) = \frac{2(s+5)}{(s+2)(s+3)(s+4)}$ **(May 2018)**
20)	Consider a linear system described by the following transfer function, $\frac{Y(s)}{U(s)} = \frac{10}{s(s+1)(s+2)}$ Design a feedback controller with a state feedback so that the closed loop poles are placed at -2. -1±j1. **(May 2018)**
21)	Consider the following RLC series circuit shown in figure below and obtain its state model. **(May 2019)**



22)	Consider the following plant of the state space representation $$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}\ B = \begin{bmatrix} -2 \\ 2 \end{bmatrix}\ C = [-2 \quad 0]$$ Examine the controllability and observability of a state-space formed by the system**. (May 2019)**
23)	Derive the state variable formulation of parallel RLC circuit with current source input. **(Nov 2019)**
24)	i) Obtain the state model for the system described by the transfer function $T(s) = \frac{Y(s)}{U(s)} = \frac{1}{s^3 + 6s^2 + 10s + 5}$ **(May 2021)** ii) Obtain state transition matrix for the state model whose A matrix is given by $A = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$ **(May 2021)**
25)	Determine the state controllability and observability of the system $\dot{x}(t)$=Ax(t)+bu(t), y(t)=CX(t) **(May 2021)** A=$\begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \\ 0 & 0 & -1 \end{bmatrix}$, B=$\begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$, C = [1 0 1].
26)	The state model of a system is given by the given state equation. Verify that the system is controllable and observable. **(May 2022)** $$\overset{o}{X} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -5 & -1 \end{bmatrix} X + \begin{bmatrix} 0 \\ 5 \\ -24 \end{bmatrix} u$$ $$\mathbf{y} = [\mathbf{1} \quad \mathbf{0} \quad \mathbf{0}]\ \boldsymbol{x} + [\mathbf{0}]\ \boldsymbol{u}$$