INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

ELECTRONICS AND COMMUNICATION ENGINEERING

TUTORIAL QUESTION BANK

Course Name	:	**CONTROL SYSTEMS**
Course Code	:	**AEE009**
Class	:	**B. Tech IV Semester**
Branch	:	**ECE**
Academic Year	:	**2018– 2019**
Course Coordinator	:	**Dr. Lalit Kumar Kaul, Professor, ECE**
Course Faculty	:	**Dr. K. Nehru, Professor, ECE** **Mr. N Nagaraju, Assistant Professor, ECE** **Ms. M L Ravi Teja, Assistant Professor, ECE**

COURSE OBJECTIVES:

The course should enable the students to:

S. NO	DESCRIPTION
I	Develop mathematical model for electrical and mechanical systems and derive transfer function of dynamic control system using block diagram algebra and mason's gain formula.
II	Understand the effect of rise time, fall time, peak overshoot and settling time for first order and second order systems and calculate the steady state error using static error coefficients.
III	Determine the stability of the system using Routh Hurwitz array and root locus technique in time and frequency domain approach.
IV	Design a lag, lead and lag-lead compensators as also Proportional, Integral, Derivative controllers & combinations like, P+I, P+D, P+I+D.
V	Understand system responses using state variables & state equations.

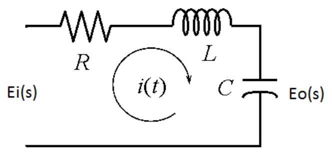
COURSE LEARNING OUTCOMES:

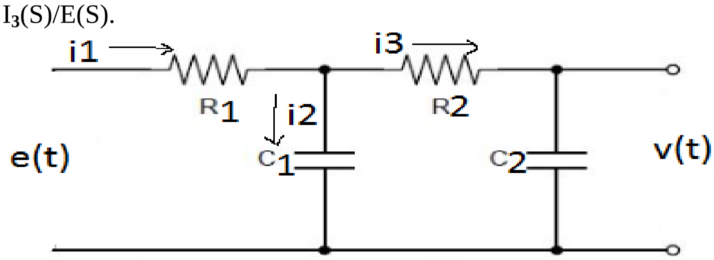
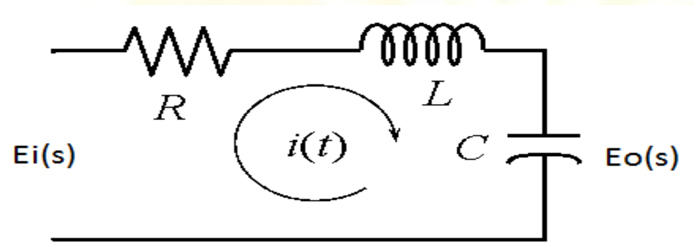
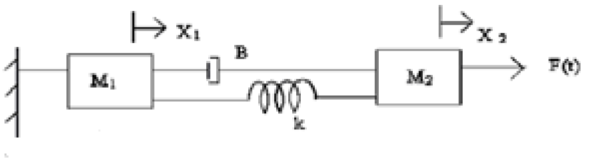
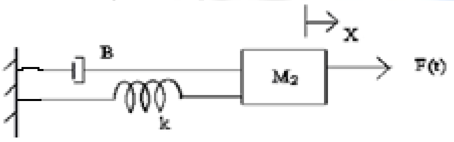
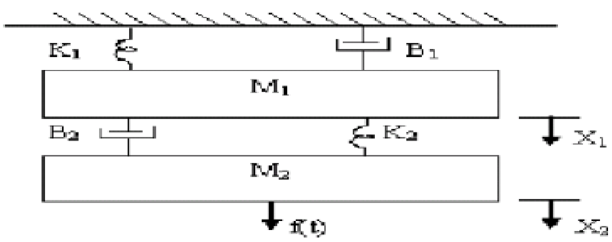
Students, who complete the course, will have demonstrated the ability to do the following:

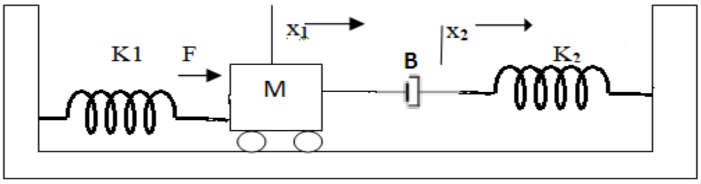
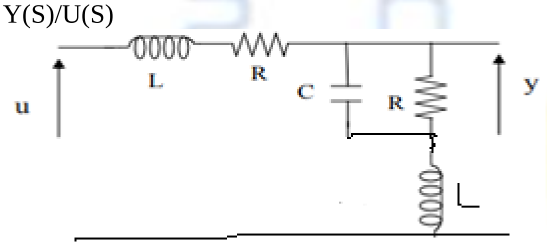
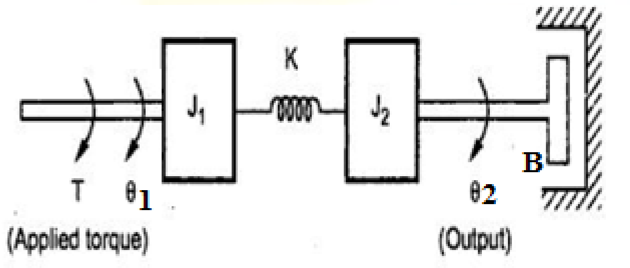
CAEE009.01	Understand the concept of open loop and closed loop systems with real time examples.
CAEE009.02	Derive the mathematical model for electrical and mechanical systems using differential equations.
CAEE009.03	Identify the equivalent model for electrical and mechanical systems using force voltage and force current analogy.
CAEE009.04	Discuss the block diagram reduction techniques and effect of feedback in open loop and closed loop systems.
CAEE009.05	Evaluate the transfer function of signal flow graphs using Mason's gain formula and Understand standard test signals for transient analysis.
CAEE009.06	Evaluate steady state errors and error constants for first and second order systems by using step, ramp and impulse signals.
CAEE009.07	Understand Routh Hurwitz stability criterion to find the necessary and sufficient conditions for stability.
CAEE009.08	Understand and Understand the design procedures of root locus for stability and discuss the effect of poles and zeros on stability.
CAEE009.09	Implement controllers using proportional integral, proportional derivative and proportional integral derivative controllers.
CAEE009.10	Understand the concept of frequency domain and discuss the importance of resonant frequency, resonant peak and bandwidth on stability
CAEE009.11	Evaluate the performance of stability using bode plot, polar plot and nyquist plot and calculate the gain crossover frequency and phase crossover frequency.

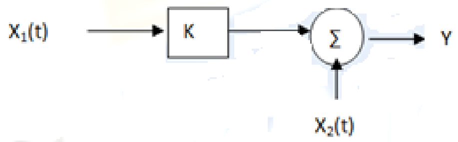
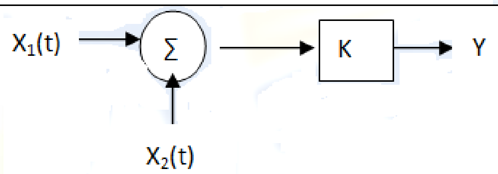
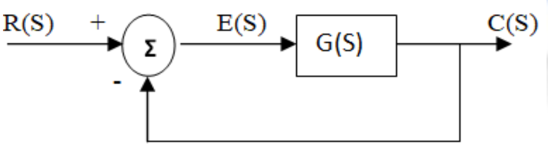
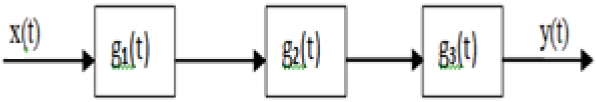
CAEE009.12	Understand the gain margin and phase margin for higher order systems and demonstrate the correlation between time and frequency response.
CAEE009.13	Understand the concept of state, state variables and derive the state models from block diagrams.
CAEE009.14	Understand state space design techniques for modeling and control system design. Formulate and solve state-variable models of linear systems
CAEE009.15	Understand analytical methods to system models: controllability, observability, and stability. Design a lag, lead and lag lead networks for stability improvement.
CAEE009.16	Understand the concept of controllers and state space designs to real time applications.
CAEE009.17	Acquire the knowledge and develop capability to succeed national and international level competitive examinations.

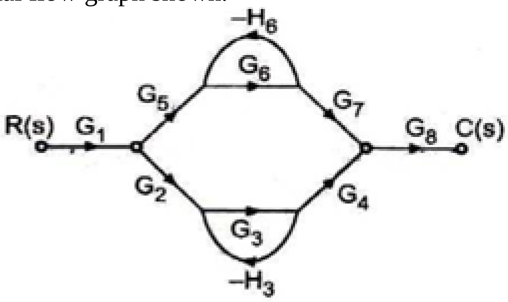
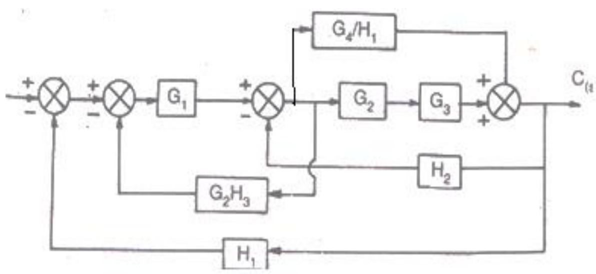
TUTORIAL QUESTION BANK

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
	UNIT-I		
	INTRODUCTION AND MODELING OF PHYSICAL SYSTEMS		
	PART-A (SHORT ANSWER QUESTIONS)		
1	What is a control system.	Understand	CAEE009.01
2	Define open loop system.	Understand	CAEE009.01
3	Define closed loop system.	Understand	CAEE009.01
4	Define transfer function.	Remember	CAEE009.01
5	Write the force balance equations of a spring element.	Understand	CAEE009.02
6	Write the analogous electrical elements in force voltage analogy for the elements of mechanical translational system.	Remember	CAEE009.02
7	Explain open loop & closed loop control systems by giving suitable examples & highlight demerits of closed loop system.	Understand	CAEE009.02
8	Explain the difference between open loop and closed loop systems.	Remember	CAEE009.02
9	Explain briefly the importance of mathematical model of a physical system.	Understand	CAEE009.02
10	What are the basic elements used for modeling mechanical rotational system.	Remember	CAEE009.02
11	Write the torque balance equation of ideal dash-pot element.	Understand	CAEE009.02
12	Write the torque balance equation of ideal rotational mass element	Remember	CAEE009.02
13	Write the force balance equations of ideal mass element.	Understand	CAEE009.02
14	Write the force balance equations of dashpot element.	Remember	CAEE009.02
15	What are the basic elements used for modeling mechanical translational system.	Remember	CAEE009.02
	PART-B (LONG ANSWER QUESTIONS)		
1	Write the differential equation for R-C integrator.	Understand	CAEE009.01
2	Write the differential equation for R-C differentiator.	Remember	CAEE009.01
3	Write the differential equation for R-L integrator.	Understand	CAEE009.02
4	Explain the classification of control systems.	Remember	CAEE009.01
5	Determine the transfer function of RLC series circuit if the voltage across the capacitor is an output variable and input is voltage source Ei(S). 	Understand	CAEE009.02
6	A single input – single output system with zero initial conditions is described by the differential equation $d^4x/dt^4 + 2* d^3x/dt^3 + 3* d^2x/dt^2 + 1.5* dx/dt +0.5 *x(t) = f(t) + 0.5 df/dt + 0.2 d^2f/dt^2$ Determine the transfer function X(S)/F(S). Assume zero initial conditions	Understand	CAEE009.02

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
7	The transfer function of a system is given by $$\frac{Y(s)}{X(s)} = G(s) = \frac{s^3 + 3s^2 + 2s + 1}{s^5 + 4s^4 + 3s^3 + 2s^2 + s + 1}$$ Determine the differential equation governing it.	Understand	CAEE009.02
8	For the system shown below, determine the transfer function $I_3(S)/E(S)$.  	Understand	CAEE009.02
9	Determine the transfer function of RLC parallel circuit if the voltage across the capacitor is output variable and input is current source i(s).	Understand	CAEE009.02
10	For the network shown below, determine the transfer function $V_R(s)/E_i(s)$, where $V_R(s)$ is the voltage across the resistor, R.  	Understand	CAEE009.02
	PART-C (PROBLEM SOLVING AND CRITICAL THINKING QUESTIONS)		
1	Write the differential equations governing the Mechanical system shown in fig. and determine the transfer function  	Understand	CAEE009.02
2	Write the differential equations governing the Mechanical system shown in fig. and equation for its force voltage equivalent circuit.  	Understand	CAEE009.02
3	Write the differential equations governing the Mechanical system shown in figure.  	Understand	CAEE009.02

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
4	For the system shown below, determine the differential equations governing the translational motions of mass M. also write the laplace domain formulation for the differential equations, when force is applied at t=0.  	Understand	CAEE009.02
5	For the electrical circuit shown in figure. Derive the transfer function Y(S)/U(S)  	Understand	CAEE009.02
6	Obtain the transfer function $\Theta_1(s)/T(s)$ of the following mechanical system  	Understand	CAEE009.02
7	Derive the transfer function for armature controlled DC motor	Understand	CAEE009.02
8	Derive the transfer function for AC servomotor	Understand	CAEE009.02
9	Derive torque balance equation for a gear train when load is refered to the motor side.	Understand	CAEE009.02
10	Derive the transfer function for field controlled DC motor	Understand	CAEE009.02
	UNIT-II		
	BLOCK DIAGRAM REDUCTION AND TIME RESPONSE ANALYSIS		
	PART-A(SHORT ANSWER QUESTIONS)		
1	What is the difference between a loop and a forward path?	Remember	CAEE009.05
2	Define sink node and source node.	Understand	CAEE009.05
3	Write Masons Gain formula.	Remember	CAEE009.05
4	Draw a forward path connecting three nodes A, B, C.	Remember	CAEE009.05
5	Can a forward path pass through a node more than once?		
6	Two loops have a node common to them; are they touching or non touching loops.	Understand	CAEE009.05
7	Draw a summing junction which as three inputs and one output.	Understand	CAEE009.04
8	G(s)=K/(s+a); determine error constants Kp and Kv	Remember	CAEE009.05
9	Write mathematical expression for a unit ramp and ramp with slope K.	Understand	CAEE009.06
10	G(s)=K/(s+a); find its impulse response.	Understand	CAEE009.06
11	The characteristic equation is $S^2 + PS + 4=0$. For a critically damped system, determine value of P.	Remember	CAEE009.06
12	Distinguish between type and order of a system. Can type of a system be higher than its order?	Remember	CAEE009.06

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
13	For a second order under damped system, write the expression for percentage overshoot and time to first peak.	Remember	CAEE009.06
14	For the shown block diagram shift block K to the right of summing junction and redraw the block diagram without altering the relationship between the inputs X_1 and X_2 and output Y 	Understand	CAEE009.06
15	 Shift the gain K block to the left of summing junction and redraw the block diagram without changing the relationship between output Y and inputs X_1 and X_2.	Understand	CAEE009.06
	PART-B (LONG ANSWER QUESTIONS)		
1	Given G(S)=5/(S+5); determine its step response.	Remember	CAEE009.06
2	A unity feedback system has G(S) = 10/S(S+20); determine its characteristic equation and location of its roots.	Understand	CAEE009.06
3	Plot the functions U(t), U(t-T), U(t+T), δ(t), δ(t-T), δ(t+T) and express them in Laplace transform domain.	Understand	CAEE009.04
4	The over damped second order system transfer function, G(S) = 10/(S+1)(S+2)(S+5). Determine its response for a unit step input. State why the system is over damped.	Understand	CAEE009.06
5	The transfer function of a system is given by G(S) = 1/(S+ a). Using convolution integral determine its output response for a unit step input and unit impulse input.	Understand	CAEE009.06
6	Write Mason's gain formula and explain its various terms.	Understand	CAEE009.05
7	Determine K_p and K_v for a unity feedback system with G(S) = 10/S(S+1), and write the expression for the close loop transfer function C(S)/R(S), where C(S) is output and R(S) is input. Draw the block diagram for closed loop system.	Understand	CAEE009.06
8	For the unity feedback system shown below, determine the transfer function C(S)/R(S) 	Understand	CAEE009.05
9	An input x(t) is applied to a system with impulse response g(t). The output y(t) is convolution of g(t) with x(t) represented as $y(t) = g(t) * x(t)$ Write the input-output relationship for the system given below, in terms of convolution integral. 	Understand	CAEE009.06
10	Using Mason's gain formula obtain the overall transfer function C/R	Understand	CAEE009.05

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
	from the signal flow graph shown. 		
PART-C (PROBLEM SOLVING AND CRITICAL THINKING QUESTIONS)			
1	For a R-C integrator derive its transfer function. Using convolution integral determine its output response for a unit step input. The time constant for the integrator is 2 Seconds, assume R=1K ohms. Find the value of C.	Understand	CAEE009.06
2	A feedback control system is described as G(s) = 50/S(S+2)(S+5) , H(S) = 1/S For a unit step input, determine the steady state error & error constants.	Understand	CAEE009.06
3	The closed loop transfer function of a unity feedback control system is given by C(S)/R(S) = 10/(S^2+4S+10) Determine (i) Damping ratio (ii) Natural undammed resonance frequency (iii) Percentage peak overshoot (iv) Rise time (v) Time to first peak	Understand	CAEE009.06
4	The open loop transfer function of a unity feedback system is given by G(S) = K/S(1 + TS), where K and T are positive 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%.	Understand	CAEE009.06
5	The forward transfer function of a unity feedback type1, second order system has a pole at -2. The nature of gain k is so adjusted that damping ratio is 0.4. The above equation is subjected to input r(t)=1+4t. Find steady state error.	Understand	CAEE009.06
6	The open loop transfer function of a control system with unity feedback is given by G(s) = 100/S (1+0.1 S). Determine the steady state error of the system when the input is 10+10t+4t^2	Understand	CAEE009.06
7	Using Mason's gain formula, determine the overall transfer function C(S)/R(S) for the system shown in figure with input as R(S). 	Understand	CAEE009.04
8	Determine the transfer function C(S)/R(S) of the system shown below using block diagram reduction method.	Understand	CAEE009.04

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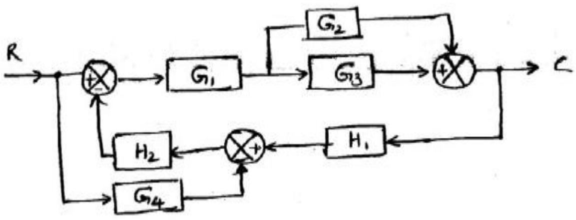
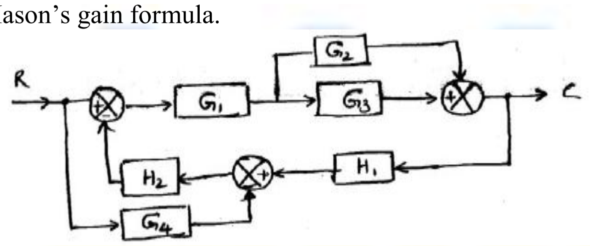
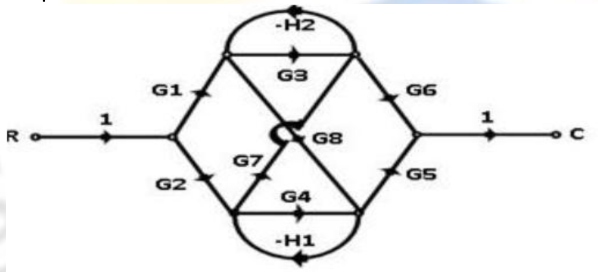
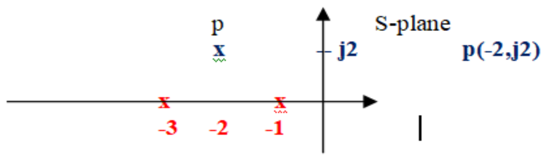
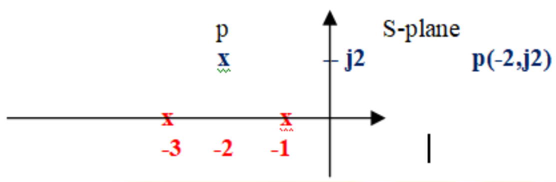
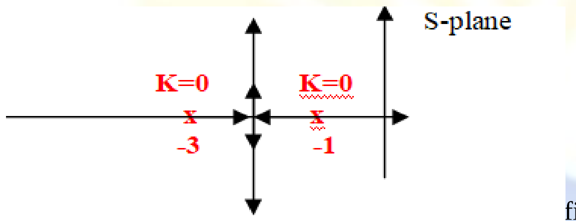
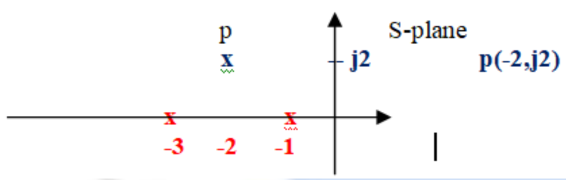
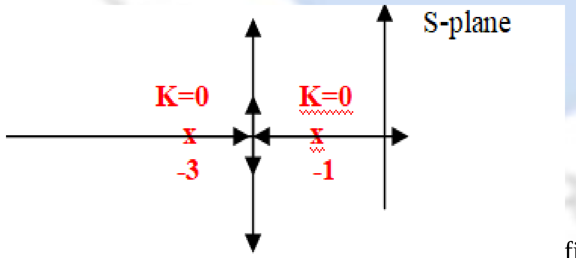
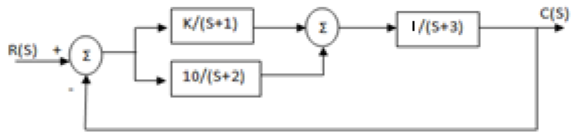
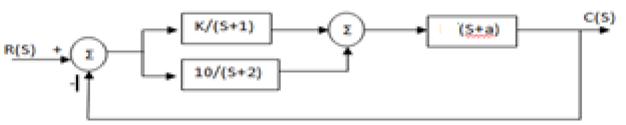
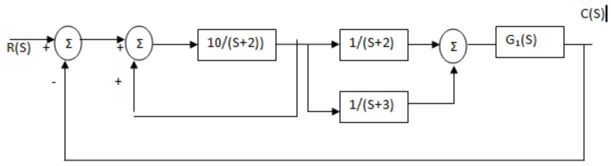
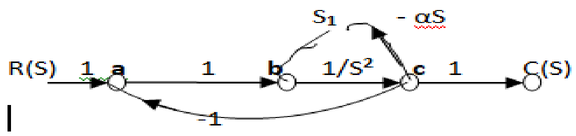
			
9	Determine the transfer function C(S)/R(S) of the system shown below using Mason's gain formula. 	Understand	CAEE009.04
10	Find the number of a) Forward paths b) Independent loops c) Two non touching loops d) Three non touching loops. Give the expression for determinant 	Understand	CAEE009.05
UNIT-III			
STABILITY ANALYSIS AND CONTROLLERS			
CIE-I			
PART-A(SHORT ANSWER QUESTIONS)			
1	Define BIBO Stability. What is the necessary condition for stability?	Remember	CAEE009.07
2	What is characteristic equation? How the roots of characteristic equation are related to stability.	Remember	CAEE009.07
3	What is the relation between stability and coefficient of characteristic polynomial?	Understand	CAEE009.07
4	What will be the nature of impulse response when the roots of characteristic equation are lying on imaginary axis?	Understand	CAEE009.07
5	What will be the nature of impulse response if the roots of characteristic equation are lying on right half s-plane?	Remember	CAEE009.07
6	What is auxiliary polynomial?	Understand	CAEE009.07
7	The characteristic equation of a system is $Q(S) = S^3 – S^2 + 1 = 0$ State by inspection whether the system will be stable or unstable. If unstable, write reasons for the same.	Understand	CAEE009.07
8	Is relative stability of a closed loop system determinable using Routh's criterion.	Understand	CAEE009.07
9	Open loop transfer function for a unity feedback system is given by $G(S)= K/(S+2)\ S^2+4S+5)$. Determine its characteristic equation.	Understand	CAEE009.07

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
10	$G(S) = 10/ (S^2 + a^2)$. Discuss the stability of G(S).	Understand	CAEE009.07
11	If all the elements in Routh's table become zero, what is the nature of closed loop poles?	Understand	CAEE009.07
12	Define absolute & limitedly stable system.	Understand	CAEE009.07
13	The characteristic equation is given by s-a = 0. Is the system stable?	Understand	CAEE009.07
14	Determine the poles and zeros for G(S)=40(s+2)(s+6)/(s+4)(s+5)	Understand	CAEE009.07
15	The characteristic equation is given by $S^2 + 2S + 1 = 0$. Determine stability using routh array.	Remember	CAEE009.07
CIE-II			
1	What criteria are followed for drawing root locus in the S-plane?	Understand	CAEE009.08
2	For a rational transfer function, under what condition asymptotes are required for drawing root locus?	Remember	CAEE009.08
3	Define centroid, how it is calculated?	Understand	CAEE009.08
4	What is breakaway and breakin point? How to determine them?	Remember	CAEE009.08
5	What is dominant pole? If there are 2 poles of G(S) at S= -0.01 and -2.0 of the two which one is a dominant pole?	Understand	CAEE009.08
6	How will you find root locus on real axis?	Understand	CAEE009.08
7	Write the transfer function a proportional plus integral controller?	Remember	CAEE009.09
8	Write the transfer function of a PID controller?	Remember	CAEE009.09
9	What is the advantage of PD controller?	Understand	CAEE009.09
10	Write the formula for determining angle of asymptotes.	Understand	CAEE009.09
11	What is the effect of PI controller on the system performance?	Understand	CAEE009.09
12	Does PI controller introduce phase lag or lead between its output and input variables?	Remember	CAEE009.09
13	Write the magnitude criterion of root locus?	Remember	CAEE009.08
14	Write the angle criterion of root locus?	Understand	CAEE009.08
15	If there is a pole zero cancellation in G(S), where does the closed loop pole lie in the root locus?	Remember	CAEE009.08
PART-B(LONG ANSWER QUESTIONS)			
1	For $G(S) = K/(S^3 + 2S^2 + 3S + 4)$.Using Routh's criteria, determine range of K for stable system.	Understand	CAEE009.07
2	Open loop transfer function for a unity feedback system is given by $G(S)=K/(S+2)(S^2+4S+5)$. Determine its characteristic equation. Using Routh's criteria find the range of gain K for which the closed loop system is stable. Can it be said that the system is absolutely stable?	Understand	CAEE009.07
3	Open loop transfer function for a unity feedback system is given by $G(S) = K/ S^3 + 2S^2 + 3S – b$; $H(S) = \alpha$. Is the open loop system stable? Using Routh Hurwitz criteria, determine the conditions relating b, K and α so that the closed loop system is stable. Satisfying the conditions choose appropriate values for b, K and α and show that the closed	Understand	CAEE009.07

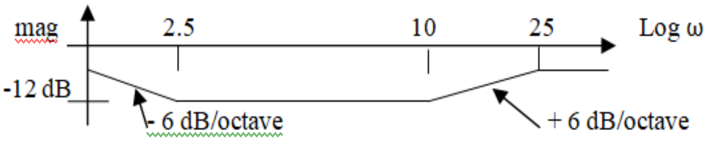
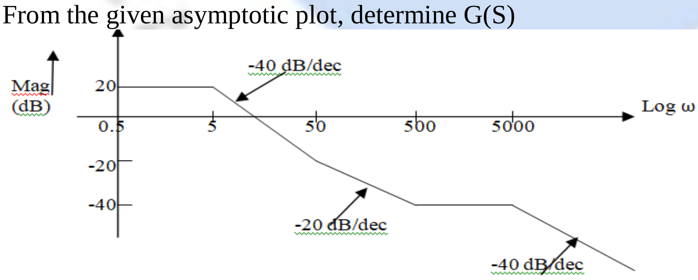
S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
	system is stable.		
4	By means of Routh criterion, determine the stability represented by characteristic equation, $s^4+2s^3+8s^2+4s+3=0$.	Understand	CAEE009.07
5	Open loop transfer function for a unity feedback system is given by $G(S)=K/(S+2)(S^2+4S+5)$. Determine the range of K so that the closed loop poles lie to the left of S= -1 point in the S-plane. Use Routh - Hurwitz criteria.	Understand	CAEE009.07
6	Using the Routh's criterion determine the stability of the system represented by characteristic equation $s^4+8s^3+18s^2+16s+5=0$.	Understand	CAEE009.07
7	Using the Routh's criterion determine the stability of the system represented by characteristic equation $s^4+18s^3+8s^2+8s+5=0$.	Understand	CAEE009.07
8	G(S) = K/S(S+1). Determine the range of K for closed loop system to be stable using Routh's criteria. Now a pole in the G(S) is introduced at S= -3. Determine range of K for closed loop system to be stable using Routh's criteria. Which of the two systems is conditionally stable?	Understand	CAEE009.07
9	$G(S)= K/(S+1)(S^2 + S+1)$. Determine the range of K for closed loop system to be stable using Routh's criteria. A zero is introduced at S= -2 in G(S). Determine the range of K for closed loop system to be stable using Routh's criteria. Which of the two systems has wider range of K for stability?	Understand	CAEE009.07
10	The open loop system is given by $G(S)= K/(S^2-aS+b)$. Comment on its stability. What should be the feedback element H(S) so that the closed loop system is stable? Determine the conditions of stability using Routh's criteria.	Understand	CAEE009.07
CIE-II			
1	a) Derive the expression for phase response, φ(ω), for a P+I controller. Is its magnitude response independent of frequency, ω? b) Derive the expression for phase response, φ(ω), for a P+D controller. Is its magnitude response independent of frequency, ω?	Understand	CAEE009.09
2	P+D controller is expressed in two forms as below $G_{C1}(S)= K_P+K_DS$ and $G_{C2}(S) =K_P+K_DS/(1+T_DS)$. Draw their phase plots and explain the difference between the two. Choose $T_D=0.2$.	Understand	CAEE009.09
3	P+I controller is expressed in two forms as below $G_{C1}(S)= K_P+K_I/S$ and $G_{C2}(S) =K_P+K_I/(1+T_IS)$. Draw their phase plots and explain the difference between the two. Choose $T_I=0.2$.	Understand	CAEE009.09
4	a) Derive the expression for magnitude response, M(ω), for P+I+D controller. b) Derive the expression for magnitude response, M(ω), for P+I controller.	Understand	CAEE009.09
5	Plot pole – zero locations for $G(S) = 10(S+2)(S+4)/S(S+6)(S^2+S+1)$ in the S-plane. Determine a) Number of asymptotes b) Angle of asymptotes c) centroid	Understand	CAEE009.08

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
6	G(S) = K/ (S+1)(S+3). Using root locus method, calculate the value of K at point ‘p’ in the S-plane. Determine the angle subtended by the two poles at point ‘p’ in the S-plane 	Understand	CAEE009.08
7	For the pole zero configuration in figure-1, the root locus is shown in figure-2. A zero is added at S = -4 in G(S). Plot the locus for this case. Discuss the effect.  figure-1  figure-2	Understand	CAEE009.08
8	For the pole zero configuration in figure-1, the root locus is shown in figure-2. A pole is added at S = -4 in G(S). Plot the locus for this case. Discuss the effect.  figure-1  figure-2	Understand	CAEE009.08
9	Calculate % overshoot for ξ= 0.4. Determine ξ so that % overshoot reduces to 0.15. Which of the two is relatively more stable?	Understand	CAEE009.08
10	G(S) = K(S+4)(S+10)(S+8)/(S+2)(S+6)(S+10)(S+15). For K ⟶ ∞, determine the location of closed loop poles. Is the closed loop system underdamped, overdamped or undamped.	Understand	CAEE009.08
PART-C (PROBLEM SOLVING AND CRITICAL THINKING QUESTIONS)			
1	The system is governed by the differential equation $d^6x/dt^6+5d^5x/dt^5+4d^4x/dt^4+3d^3x/dt^3+2d^2x/dt^2+dx/dt+6=f(t)$. Determine its stability using Routh’s criteria.	Understand	CAEE009.07
2	System block diagram is as shown below. Using Routh criteria find the	Understand	CAEE009.07

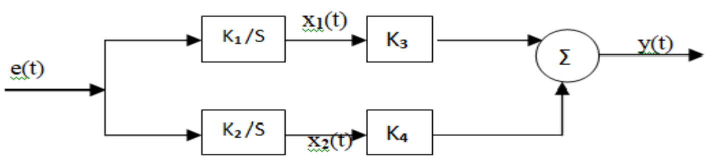
S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
	range of K for system to be stable. 		
3	For the unity feedback system the open loop T.F. is $G(s) = \frac{K}{S(1+0.6S)(1+0.4S)}$ Determine a) Number of asymptotes b) Angle of asymptotes c) Centroid d) Draw the pole zero locations	Understand	CAEE009.07
4	Open loop transfer function for a non-unity feedback system is given by G(S) = K/ (S +2) (S + 7)(S^2+4S+5) & H(S) = (S + 3). Find the value of K for which the closed loop system will be on verge of stability. Find the frequency of sustained oscillations using Routh's criteria.	Understand	CAEE009.07
5	The system having characteristic equation $2s^4+4s^2+1=0$ (i) The number of roots in the left half of s-plane (ii) The number of roots in the right half of s-plane (iii) The number of roots on imaginary axis use RH stability criterion.	Understand	CAEE009.07
6	Determine the value of 'a' so that the forward path transfer function does not have a pole at S=-2. Determine its characteristic equation. 	Understand	CAEE009.07
7	G(S) = K/(S^3 –aS^2-bS+c). Determine the feedback path transfer function H(S) for closed loop system to be stable. Determine the conditions for stability using Routh's criteria	Understand	CAEE009.07
8	The characteristic equation is given by $S^3+aS^2+bS+c=0$. Fnd the relationship between a, b,c for the characteristic equation to have a pair of conjugate roots.Give the expression for frequency of oscillation.	Understand	CAEE009.07
9	G(S) = K/S(S+2)(S^2+4S+10)(S+3). Determine the range of K for stability of closed loop system. Value of K for closed loop poles to lie on the imaginary axis of the S-plane. Find the value of K for which the system will be unstable.	Understand	CAEE009.07
10	For the block diagram shown in the figure, determine the value of G1(S) so that the forward path transfer function does not have a pole in the right half of the S-plane. Determine the characteristic equation for the closed loop system. 	Understand	CAEE009.07

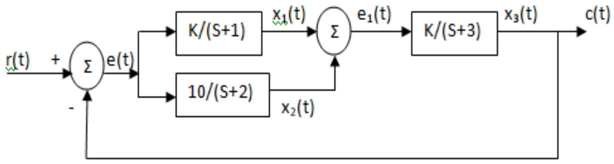
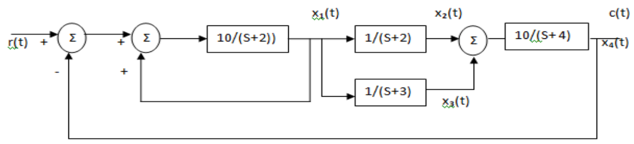
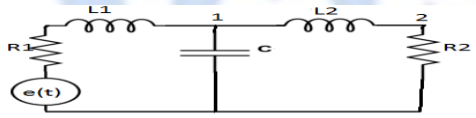
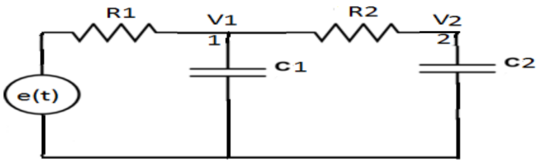
S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
	CIE-II		
1	For G(S) = K(S+b)/S(S+a). Show that the root locus is a circle with center at (-b,0) and radius = $\sqrt{(b^2-ab)}$.	Understand	CAEE009.08
2	Open loop transfer function for a non-unity feedback system is given by G(S) = K/ (S +2) (S + 7)(S^2+4S+5) & H(S) = (S + 3) Determine, 1) Centroid, 2) Angle of asymptotes, 3) Maximum value of K for which the closed loop system will be conditionally stable (on the verge of instability), 4) Frequency of oscillation for the closed loop system.	Understand	CAEE009.08
3	Open loop transfer function for a unity feedback system is given by G(S) = K /(S + 2) (S+ 4) (S + 6)(S+ 8) Using root locus method, determine, the value of K at S = -1.0 + j 2.0, 2 break away points	Understand	CAEE009.08
4	Open loop transfer function for a unity feedback system is given by G(S) = 10/ (S+2)(S+3). In the forward path P+D controller of the form (1 + K_D S) is introduced. Write the characteristic equation for the system. From the characteristic equation determine the expression for open loop transfer function that can be used to draw the root locus for the range of K_D ; $0 < K_D < \infty$. Determine 1) break away point, 2) angle of departure from poles.	Understand	CAEE009.08
5	Open loop transfer function for a unity feedback system is given by G(S) = 10/(S + 3). In the forward path P+I controller of the form (1 + K_I/S) is introduced. Write the characteristic equation for the system. From the characteristic equation determine the expression for open loop transfer function that can be used to draw the root locus for the range of K_I ; $0 < K_I < \infty$. Draw the location of poles & zeros for the derived open loop transfer function. Determine the value of K_I at S= -2.0 & -15.0.	Understand	CAEE009.08
6	Open loop transfer function is given by G(S) = K/ (S + 2) (S + 4) (S + 8). The feedback element is a (P+D) controller given by, H(S) = 1 + 0.25 S. Using root locus method, list the location of one of the closed loop poles in the S-plane. Determine 1) break away point, 2) number & angle of asymptotes,3) value of natural frequency of oscillation for K = 10, 4) location of closed loop poles for K = 10.	Understand	CAEE009.09
7	Controller transfer functions are given by G_{C1}(S) = (S+z)/(S+p). Break this transfer function into I + D controller. G_{C2}(S) = (S+2)(S+1)/(S+4)(S+6). Decompose G_{C2}(S) into a cascade of I + D controllers. How many number of cascade combinations can be designed?	Understand	CAEE009.09
8	The signal flow diagram of a control system is shown in figure  a) Comment on stability of system when the switch s_1 is open b) When s1 is closed show that the root locus with α as varying parameter is a circle with center at σ= 0, ω=0 and radius =1. Draw a line on root locus for ξ = 0.5. Determine the value of complex conjugate poles for ξ = 0.5.	Understand	CAEE009.08

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
9	The open loop system is governed by the differential equation $d^3x/dt^3+2d^2x/dt^2+ 2dx/dt+ K x = f(t)$. Determine a) location of poles of open loop system G(S) b)number of zeros of G(S) at ∞ c)number of asymptotes d)angle of asymptotes e)centroid For the range of K: 0<K≤∞.	Understand	CAEE009.08
10	For system-1 the PID controller transfer function is given by $G_1(S) = K_P + K_I/S + K_D S$ and for the system-2 the PID controller is given by the transfer function $G_2(S) = K_P + K_I/(1+T_I S) + K_D S/(1+T_D S)$. State: a) Which of the two controllers has ideal integrator and differentiator b) Which of the two controllers has non-ideal integrator and differentiator c) The difference between ideal and non ideal integrator d) The difference between ideal and non ideal differentiator e) Whether ideal integrator and differentiator can be assembled (designed) using passive elements like R and C.	Understand	CAEE009.09
UNIT-IV			
FREQUENCY DOMAIN ANALYSIS			
	PART-A (SHORT ANSWER QUESTIONS)		
1	What is frequency response	Remember	CAEE009.10
2	What are frequency domain specifications	Understand	CAEE009.10
3	Define bandwidth of a system.	Remember	CAEE009.10
4	Give the formula for determining gain margin from Bode plot	Understand	CAEE009.11
5	State Nyquist criteria for stability of a closed loop system.	Understand	CAEE009.11
6	Give the formula for determining phase margin from Polar plot	Understand	CAEE009.11
7	Define gain margin	Understand	CAEE009.12
8	Define corner frequency.	Remember	CAEE009.11
9	Define cut-off rate.	Remember	CAEE009.11
10	Define resonant peak(Mr)	Remember	CAEE009.10
11	Define gain-cross over frequency (ω_{gc}).	Remember	CAEE009.10
12	Define phase-cross over frequency (ω_{pc}).	Remember	CAEE009.11
13	Define phase margin.	Remember	CAEE009.11
14	How gain and phase margin be improved?	Remember	CAEE009.12
15	List the advantages of bode plots.	Remember	CAEE009.11
PART-B (LONG ANSWER QUESTIONS)			
1	For damping ratio, ξ = 0.5, normalized frequency (u)=1, determine 1) % overshoot, 2) Resonant peak, and 3) phase angle at resonant frequency, for a second order system.	Understand	CAEE009.10
2	A system has transfer function G(S) = 1/(S + 1). An input signal x(t) = V Sin ωt is applied to it. The output of the system is y(t). Write the expression for output y(t) under steady state.	Understand	CAEE009.10
3	For G(S) = 10/ (1+0.5 S)(1 + 0.25 S), write expression for G(ω) = |G(j ω)| and φ(ω) = arg (G(jω)). Find the value of G(ω) and φ(ω) at ω =2 rad/s.	Understand	CAEE009.10
4	G(S) = 10/ (1+0.5 S)(1 + 0.25 S); determine intersection on real & imaginary axis of the S-plane.	Understand	CAEE009.10
5	Sketch the Bode plot for the open loop transfer function $G(s) = \frac{10(S+3)}{S(S+2)(S+5)}$ and determine phase and gain margins	Understand	CAEE009.11
6	Given the open loop transfer function $\frac{20}{s(1+3s)(1+4S)}$. Draw the Bode plot	Understand	CAEE009.11

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
	and determine phase and gain margins.		
7	a) G(S) = 1/ (1 + S); determine phase cross-over frequency using polar plot. b) G(S) = 1/(1 + 0.25 S) (1 + 0.5 S) (1+ 2 S); determine corner frequencies. What will be the maximum attenuation rate for its Bode magnitude plot?	Understand	CAEE009.11
8	Draw pole locations & Nyquist Contour for the following transfer functions G(S) = 1/S(S + 1)(S + 2) & G(S) = 1/(S + 1)(S +2)	Understand	CAEE009.11
9	a) For Mr = 1.1547, determine ξ and Mp b) For Mp = 0.25, determine ξ and Mr	Understand	CAEE009.10
10	The open loop transfer function of a system is $G(s) = \frac{K}{S(1+S)(1+0.1S)}$ Using Bode plot determine the value of K such that (i) Gain Margin = 10dB and (ii) Phase Margin = 50 degree	Understand	CAEE009.12
PART-C (PROBLEM SOLVING AND CRITICAL THINKING QUESTIONS)			
1	By Nyquist stability criterion determine the stability of closed loop system, whose open loop transfer function is G(S)H(S) = $\frac{(S+2)}{(s+1)(s-1)}$. Comment on stability of open loop and closed loop system.	Understand	CAEE009.10
2	Consider a unity feedback system having open loop transfer function G(s)= $\frac{K}{s(1+0.5S)(1+4S)}$.Sketch the polar and determine the value of K (i) gain margin is 20db (ii) phase margin is 30^o	Understand	CAEE009.10
3	From the given magnitude plot, determine the transfer function G(S)  	Understand	CAEE009.12
4	From the given asymptotic plot, determine G(S)  	Understand	CAEE009.12
5	G(S) = K/(1 + T_1 S) (1 + T_2 S) (1 + T_3 S) Determine frequency at intersection with real & imaginary axis respectively, in polar plot.	Understand	CAEE009.11
6	Given the transfer function G(s)= $\frac{Ks^2}{(1+0.2s)(1+0.02s)}$ Find the value of K such that it's gain cross over frequency is 5 rad/sec.	Understand	CAEE009.11
7	Draw Nyquist plot for G_1(S) = K/(S-1) & G_2(S) = K/(1-S) Determine stability of the closed loop system in both the cases. Find the value of K for stability. Is there any value of K for which closed loop system	Understand	CAEE009.11

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
	corresponding to $G_2(S)$ will be stable?		
8	Sketch the Polar plot of a system $G(s) = \frac{10}{(s+3)\,(s+4)}$ Determine its phase margin and gain margin.	Understand	CAEE009.11
9	The open loop transfer function of a unity feedback system is given by $G(S) = K/S\,(1+T_1S)(1+T_2S)$ Derive an expression for gain K in terms of T_1, T_2 and gain margin, GM.	Understand	CAEE009.12
10	Sketch Nyquist plot for $G(S) = \frac{1}{s(s+1)(s+2)}$ with unity feedback system and determine its stability.	Understand	CAEE009.12
UNIT-V			
STATE SPACE ANALYSIS AND COMPENSATORS			
PART-A(SHORT ANSWER QUESTIONS)			
1	What is lead compensator?	Understand	CAEE009.15
2	What is lag compensator?	Understand	CAEE009.15
3	What is lag-lead compensator?	Understand	CAEE009.15
4	Define observability?	Understand	CAEE009.15
5	Define controllability?	Remember	CAEE009.15
6	What are Eigen values?	Remember	CAEE009.14
7	What are draw backs of transfer function model analysis?	Understand	CAEE009.13
8	What is state, state variable and state vector?	Understand	CAEE009.13
9	What are the properties of state transition matrix?	Remember	CAEE009.13
10	What are the advantages of state space analysis?	Remember	CAEE009.13
11	Draw pole – zero diagram of lead compensator?	Understand	CAEE009.14
12	What are the two situations in which compensation is required?	Understand	CAEE009.15
13	Draw pole – zero diagram of lag compensator?	Understand	CAEE009.15
14	Draw pole – zero diagram of lead - lag compensator?	Understand	CAEE009.15
15	Draw pole – zero diagram of lag – lead compensator?	Understand	CAEE009.15
PART-B(LONG ANSWER QUESTIONS)			
1	Write properties of state transition matrix?	Understand	CAEE009.13
2	a) The state equation is given by, $dx/dt + a\,x(t) = f(t)$ How many states the system has? Write the equation for its state transition matrix. b) A system is governed by $d^2x/dt^2 + a\,dx/dt + b\,x(t) = f(t)$ How many states the system has? What will be the dimension of its ‘A’ matrix?	Understand	CAEE009.13

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
3	a) The state matrix is given by $A=\begin{bmatrix} 2 & 1 \\ -2 & 1 \end{bmatrix}$ Determine its eigen values. b) System transfer function is $G(S)=10/(S^2+3S+2)$. Represent it in cascade form.	Understand	CAEE009.13
4	a) G(S) = (1 + 0.5S)/(1 + 0.2S) Is it a lead or lag network? If yes, explain why? b) For a purely resistive network, does a state equation exist? Explain.	Understand	CAEE009.15
5	The following matrices are given , find out which are singular $X = \begin{vmatrix} A & B \\ A & B \end{vmatrix}$ $Y = \begin{vmatrix} A & B \\ -A & B \end{vmatrix}$ $Z= \begin{vmatrix} A & -B \\ -A & B \end{vmatrix}$	Understand	CAEE009.15
6	State and explain controllability and observability?	Understand	CAEE009.15
7	Write the necessary and sufficient conditions for complete state controllability and observability?	Understand	CAEE009.15
8	G(S) = 10/(S+1)(S+2)(S+3). Represent G(S) in parallel form and write its state equations.	Understand	CAEE009.14
9	For the system shown below, determine for which condition it is controllable, observable, both controllable and observable. $x_1(t)$ & $x_2(t)$ are state variables and y(t) is its output variable.  Explain your answers in short.	Understand	CAEE009.15
10	$G(S) = (1+T_1S)/(1+T_2S)$ What should be the relationship between T_1 & T_2, if a) G(S) is a lag network b) G(S) is a lead network c) Determine expression for magnitude response and calculate the magnitude at a frequency $\omega = 1/T_2$	Understand	CAEE009.13
PART-C (PROBLEM SOLVING AND CRITICAL THINKING QUESTIONS)			
1.	Calculate the STM for the system matrix and characteristic equation for eigen value calculation $A=\begin{bmatrix} 4 & 1 & -2 \\ 1 & 0 & 2 \\ 1 & -1 & 3 \end{bmatrix}$	Understand	CAEE009.13
2	A linear time invariant system is defined by the state equation dX/dt =AX(t) + B U(t) and the output equation is defined as Y= C X(t) + DU(t). The matrices are defined as $A=\begin{bmatrix} -1 & 1 \\ 1 & -2 \end{bmatrix}$,$B=\begin{bmatrix} 0 \\ 1 \end{bmatrix}$, $C = [1 \quad 0]$ Determine the complete state response and the output response of the system for the given initial state? $X(0)=\begin{bmatrix} -1 \\ 0 \end{bmatrix}$	Understand	CAEE009.13
3	Determine the state controllability and observability of the following system $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix}=\begin{bmatrix} -3 & -1 \\ -2 & 1.5 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}+\begin{bmatrix} 1 \\ 4 \end{bmatrix}u$; C=[0 1].	Understand	CAEE009.15
4	The system transfer function G(S) = 10/(S+1)(S+2)(S+3). Decompose G(S) into its parallel form and write the state and output equations for the system. Comment about its controllability and observability.	Understand	CAEE009.13

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
5	A linear time invariant system is governed by the differential equation $d^3x/dt^3 + a_1d^2x/dt2 + a_2dx/dt + a_3x(t) = f(t)$. Write its state equations in phase variable canonical form. Draw the block diagram of the system and corresponding signal graph.	Understand	CAEE009.13
6	Write the State and output equations for the system shown in the figure. The state variables are defined by 'x' and the output variable is c(t) 	Understand	CAEE009.13
7	Write the State and output equations for the system shown in the figure. The state variables are defined by 'x' and the output variable is c(t) 	Understand	CAEE009.13
8	The system transfer function G(S) = 10/(S+1)(S+2)(S+3). Decompose G(S) into its cascade form and write the state and output equations for the system. Comment about its controllability and observability.	Understand	CAEE009.13
9	For the network shown in the figure, derive its state equation and the output equation for the outputs voltage across R2 and current through L2. 	Understand	CAEE009.13
10	The state equation for a linear time-invariant system is given by $$\begin{bmatrix} x_1^0 \\ x_2^0 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$ Determine the response of the state variables for a unit step input. The initial conditions are $x_1 = 1$ and $x_2 = 0$.	Understand	CAEE009.13
11	For the circuit shown, let voltage V_1 be defined as state variable x_1 and voltage V_2 be defined as state variable x_2.  Write he output equations for the cases when a) Voltage across C_2 is taken as output b) Voltage across C_1 and C_2 are taken as outputs c) Currents through R_1 and R_2 are taken as outputs.	Understand	CAEE009.13

S. No	QUESTION	Blooms Taxonomy Level	Course Learning Outcome
12	The state equation for a linear time-invariant system is given by $\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -2 & 1 \\ 1 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u$ Determine the response of the state variables for a unit step input. The initial conditions are $x_1 = 0$ and $x_2 = 0$.	Understand	CAEE009.13

HOD, ECE