KANDULA SRINIVASA REDDY MEMORIAL COLLEGE OF ENGINEERING
(AUTONOMOUS)

KADAPA-516005. AP

(Approved by AICTE, Affiliated to JNTUA, Ananthapuramu, Accredited by NAAC)

(An ISO 9001-2015 Certified Institution)

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

VALUE ADDED COURSE

ON

"MODERN CONTROL SYSTEMS"

Resource Person : Mr. K.KALYAN KUMAR, Asst. Professor, Dept. of EEE, KSRMCE

Mr. N.SIDDHIK, Asst. Professor, Dept. of EEE, KSRMCE

Course Coordinator: Mr. T.KISHORE KUMAR, Assistant Professor, Dept. of ME, KSRMCE

Duration: 24/11/2022 to 16/12/2022

K.S.R.M. COLLEGE OF ENGINEERING

(UGC-AUTONOMOUS)

Kadapa, Andhra Pradesh, India– 516 003

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Lr./KSRMCE/EEE/2022-23/ Date:18-11-2022

To
The Principal,
KSRMCE,
Kadapa.

Respected Sir,

Sub: Permission to Conduct Value added Course on "MODERN CONTROL SYSTEMS" from **24/11/2022**–Request- Reg.

The Department of Electrical & Electronics Engineering is planning to offer a Value Added Course on "MODERN CONTROL SYSTEMS" to B. Tech. students. The course will be conducted from **24/11/2022 to 16/12/2022**. In this regard, I kindly request you to grant permission to conduct Value Added Course.

Thanking you sir,

Yours faithfully

(T.Kishore Kumar, Asst.Professor in EEE)

Forwarded to Principal sir,
Dr. (D).S. ... 18.11.22.

Permitted
V.S.S. Murthy

K.S.R.M. COLLEGE OF ENGINEERING
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Cr./KSRMCE/EEE/2022-23/

Date: 19/11/2022

Circular

The Department of Electrical & Electronics Engineering is offering a Value Added Course on "MODERN CONTROL SYSTEMS" from **24/11/2022 to 16/12/2022** to B.Tech students. In this regard, interested students are instructed to register their names for the Value Added Course with Course Coordinator.

For further information contact Course Coordinator.

Course Coordinator: Mr. T.KISHORE KUMAR, Asst.professor, Dept. of EEE.-KSRMCE.
Contact No: 7013122231

HOD I/C
Dept. of EEE

HEAD
Department of Electrical & Electronics Engineering
K.S.R.M. College of Engineering
Kadapa -516003,

Cc to:

IQAC-KSRMCE

Department of Electrical and Electronics Engineering

List of Registered Participants

Name of the Event	**Value Added Course**
Name of the Course	**MODERN CONTROL SYSTEMS**
Date(s)	24.11.2022 to 16.12.2022
Timings	03:00 PM to 5:00 PM
Resource persons	Mr. K. KALYAN KUMAR, Asst. Prof. in EEE, KSRMCE Mr. N. SIDDHIK, Asst. Prof. in EEE, KSRMCE
Venue	SJ – 106
Faculty Coordinator	Mr. T. KISHORE KUMAR, Assistant Professor in EEE, KSRMCE

S.No	Roll Number	Name of the Student	Signature
1	209Y1A0201	A.Gopi Charan	A Gopi charan
2	209Y1A0202	A.Gangadhar	A. Gangadhar
3	209Y1A0203	A Sanjana	A Sanjana
4	209Y1A0204	B Neeraja Reddy	B. Neeraja Reddy
5	209Y1A0206	C.Ramadevi	C. Ramadevi
6	209Y1A0207	D Sai Pavan	D Sai Pavan
7	209Y1A0209	D.Dharani	D. Dharani
8	209Y1A0210	D Tejaswini	D. Tejaswini
9	209Y1A0211	G Harika	G. Harika
10	209Y1A0213	G.V.Sunil Kumar	G.V. Sunil
11	209Y1A0216	K Sai Rahul	K. Sai rahul
12	209Y1A0217	K.Likhitha	K. likhitha

S.No	Roll Number	Name of the Student	Signature
13	209Y1A0218	K.Md.Kaif Ali	
14	209Y1A0220	K Venkata Sai	
15	209Y1A0221	K Hemanth Kumar	
16	209Y1A0222	L N Sai Pavan	
17	209y1A0223	Madireddy Gowri	
18	209Y1A0225	M Chandra Bharath Kumar Reddy	
19	209Y1A0226	M.Charan Kumar	
20	209Y1A0227	M. Mahalakshmi	
21	209Y1A0228	M Pavan Kumar	
22	209Y1A0229	N.Sasi Rekha	
23	209Y1A0230	N Naveen Kumar	
24	209Y1A0231	P.Yogna	
25	209Y1A0233	P.Ravi Shankar	
26	209Y1A0235	Pothuraju Sai Vignesh	
27	209Y1A0236	R.Madhukrishna	
28	209Y1A0241	Shaik Alisha Sameera	
29	209Y1A0242	S Faiz Rehman	
30	209Y1A0244	S. Md. Sameer	
31	209Y1A0245	S.Parvez	
32	209Y1A0246	S.Sudharshan	
33	209Y1A0247	S. Shashikala	
34	209Y1A0248	S Naveed	
35	209Y1A0249	T.Pallavi	
36	209Y1A0252	V Jagadeesh	

S.No	Roll Number	Name of the Student	Signature
37	219Y5A0201	A.Nagarjuna	A.Nagarjuna
38	219Y5A0202	A. Venkata Yaswanth	A.Venkata Yaswanth
39	219Y5A0203	Busagani Chandra Kumar	B.Chandra Kumar
40	219Y5A0204	M.Srinidhi	M.Srinidhi
41	219Y5A0205	M.Lakshmi Devi	M.Lakshmidevi

Coordinator

Head of the Department

HEAD
Department of Electrical &
Electronics Engineering
K.S.R.M. College of Engineering
Kadapa -516003.

Syllabus of Value Added Course

Course Name: Modern Control Systems

Course Objectives: Students are able to learn the State Space, Describing function, phase plane and stability analysis including controllability and observability.

Course Outcomes: On successful completion of this course, the students will be able to,

1. Understand the concept of State Space Techniques.
2. Analyze the stability of linear and nonlinear Systems
3. Construct the state model of Linear Time Invariant systems and Lyapunov functions for nonlinear systems
4. Determine Eigen values state transition matrix and examine the controllability and observability of linear time invariant systems
5. Design state feedback controller and observer

UNIT-I

State variable descriptions: Concepts of state, state variables, state vector, state space model, representation in state variable form, phase variable representation.

UNIT-II

Solution of State Equations: diagonalization –state transition matrix – properties – solution of state equations of homogeneous and non-homogeneous systems.

UNIT-III

Controllability and Observability: Definition of controllability – controllability tests for continuous linear time invariant systems – Definition of observability – observability tests for continuous linear time invariant systems.

UNIT-IV

Design of Control Systems: Introduction. Pole placement by state feedback, Full order and reduced order observers.

UNIT-V

Stability: Introduction, equilibrium points – stability concepts and definitions – stability in the sense of Lyapunov - stability of linear system – methods of constructing Lyapunov functions for non-linear system: Krasovskii's method.

Text Books/Reference Books:

1. Control System Engineering by I. J. Nagarath and M. Gopal, New Age International (P) Ltd.

2. Modern Control Engineering by K. Ogata, Prentice Hall of India, 3 rd Edition, 1998.

3. Systems and Control by Stainslaw, H. Zak, Oxford Press, 2003.

4. Digital Control and State Variable Methods by M. Gopal, TMH, 1997.

SCHEDULE

Department of Electrical & Electronics Engineering Engineering

Value Added Course
On
"Engine Combustion" From 24/11/2022 to 16/12/2022

Date	Timing	Resource Person	Topic to be covered
24/11/2022	4pm to 5pm	K.Kalyan Kumar	State variable description- concepts of state
25/11/2022	4pm to 5pm	K.Kalyan Kumar	State variable, state vectors
26/11/2022	1pm to 4pm	K.Kalyan Kumar	state space model, representation in state variable form, phase variable representation.
28/11/2022	4pm to 6pm	N.Siddhik	Diagonalization
29/11/2022	4pm to 6pm	N.Siddhik	State Transition Matrix: Properties and determination
30/11/2022	4pm to 5pm	N.Siddhik	Solution of State Equation of homogeneous system
01/12/2022	4pm to 6pm	N.Siddhik	Solution of State Equation of non-homogeneous system
02/12/2022	4pm to 5pm	K.Kalyan Kumar	Controllability & Observability concepts
03/12/2022	1pm to 4pm	K.Kalyan Kumar	Controllability tests for LTI systems
05/12/2022	4pm to 5pm	K.Kalyan Kumar	Observability tests for LTI systems
06/12/2022	4pm to 5pm	K.Kalyan Kumar	Observability tests for LTI systems
07/12/2022	4pm to 6pm	N.Siddhik	Introduction to design
08/12/2022	4pm to 5pm	N.Siddhik	Pole placement by state feedback
09/12/2022	4pm to 5pm	N.Siddhik	Problem on pole placement

10/12/2022	10am to 12pm	N.Siddhik	Full order observer design
10/12/2022	2pm to 4pm	N.Siddhik	Reduced order observer design
12/12/2022	4pm to 6pm	K.Kalyan Kumar	Stability Introduction
13/12/2022	4pm to 5pm	K.Kalyan Kumar	Equilibrium points: stability concepts
14/12/2022	4pm to 5pm	K.Kalyan Kumar	Lyapunov Stability Theorems
15/12/2022	4pm to 6pm	K.Kalyan Kumar	Stability of Linear systems
16/12/2022	1pm to 3pm	K.Kalyan Kumar	Construction of Lyapunov Functions

K. Kalyan Kumar

Resource Person(s)

Coordinator(s)

HOD

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Name of theEvent: Value Added Course on "Modern Control Systems" **Venue:SJ 106**

Attendance

SNo	Reg.No	24/11	25/11	26/11	28/11	29/11	30/11	1/12	2/12	3/12	5/12
1.	209Y1A0201	AGC	AGC	AGC	AGC	AGC	AGC	AGC	AGC	AGC	AGC
2.	209Y1A0202	Alean	Alean	Alean	Alea	Alean	Alean	Ala	Ala	Ala	Ala
3.	209Y1A0203	Sanjan	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana
4.	209Y1A0204	B.@y	B@y	B@y	B.@y	B@y	B@y	B@y	B@y	B.@y	A
5.	209Y1A0206	C.Raj	C.Raj	C.Raj	C.Raj	C.Raj	C.Raj	C.Raj	C.Raj	C.Raj	C.Raj
6.	209Y1A0207	Saipavan	Saipavan	Saipavan	Saipavan	Saipavan	Saipavan	Saipavan	Saipavan	Saipavan	Saipavan
7	209Y1A0209	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani
8	209Y1A0210	D.Ly	D.Ly	D.Ly	D.Ly	D.Ly	D.Ly	D.Ly	D.Ly	D.Ly	D.Ly
9	209Y1A0211	G.Har	G.Hari	G.Havik	G.Havik	G.Havik	A	G.Havika	G.Havika	G.Havika	G.Havika
10	209Y1A0213	G.V.S	G.V.S	G.V.S	G.V.S	G.V.S	G.V.S	G.V.S	G.V.S	A	A
11	209Y1A0216	Rahul	Rahul	Rahul	Rahul	Rahul	Rahul	Rahul	Rahul	Rahul	Rahul
12	209Y1A0217	K.Ld	K.Ld	Kl	K.Ld	K.Ld	K.Ld	K.Ld	K.Ld	Kl	Kl
13	209Y1A0218	K.Sai	K.Sai	A	A	K.Sai	K.Sai	Sai	Sai	Sai	Sai
14	209Y1A0220	Km	Km	Km	Km	Km	Km	Km	Km	Km	Km
15	209Y1A0221	G.Lav	Lav	G.Lav	Lav	G.Lav	G.Lav	G.Lav	Lav	Lav	Lav
16	209Y1A0222	Saipav	Saipavan	Saipavan	Saipavan	Saipavan	Saipavan	Saipav	Saipav	Saipavan	Saipav
17	209Y1A0223	Gowri	Gowri	Gowri	Gowri	Gowri	Gowri	Gowri	Gowri	Gowri	Gowri
18	209Y1A0225	M.Gb	M.Gb	M.Gb	M.Gb	M.Gb	M.Gb	M.Gb	M.Gb	M.Gb	M.Gb
19	209Y1A0226	K.Charan	Charan	Charan	Charan	Charan	Charan	Charan	Charan	Charan	Charan
20	209Y1A0227	Maha	Maha	Maha	Maha	Maha	Maha	Maha	Maha	Maha	Maha
21	209Y1A0228	Pavan	Pavan	Pavan	Pavan	Pavan	Pavan	Pavan	Pavan	Pavan	Pavan

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Name of theEvent: Value Added Course on "Modern Control Systems" **Venue:SJ 106**

Attendance

SNo	Reg.No	6/12	7/12	8/12	9/12	10/12	12/12	13/12	14/12	15/12	16/12
22	209Y1A0229	N.Sasi	N.Sasi	N.Sasi	N.Sasi	N.Sasi	N.Sasi	N.Sasi	N.Sasi	N.Sasi	N.Sasi
23	209Y1A0230	N.Nalan	N.Nalan	N.Nalan	N.Nalan	N.Nalan	N.Nalan	N.Nalan	N.Nalan	N.Nalan	N.Nalan
24	209Y1A0231	P.Yogna	P.Yogna	P.Yogna	P.Yogna	P.Yogna	P.Yogna	P.Yogna	P.Yogna	P.Yogna	P.Yogna
25	209Y1A0233	P.Raj	P.Raj	P.Raj	A	P.Raj	P.Raj	P.Raj	A	P.Raj	P.Raj
26	209Y1A0235	Sai Vignesh	Sai Vignesh	Sai Vignesh	Sai Vignesh	Sai Vignesh	Sai Vignesh	Sai Vignesh	Sai Vignesh	Sai Vignesh	Sai Vignesh
27	209Y1A0236	madhu krish	madhu krish	madhu krish	madhu krish	madhu krish	madhu krish	madhu krish	madhu krish	madhu krish	madhu krish
28	209Y1A0241	Alu	Alu	Alu	Alu	Alu	Alu	Alu	Alu	Alu	Alu
29	209Y1A0242	A	A	Saiz	Saiz	Saiz	Saiz	Saiz	A	Saiz	Saiz
30	209Y1A0244	Shaik Sareey	Shaik Sareey	Shaik Sareey	Shaik Sareey	Shaik Sareey	Shaik Sareey	Shaik Sareey	Shaik Sareey	Shaik Sareey	Shaik Sareey
31	209Y1A0245	S.Sams	S.Sams	S.Sams	S.Sams	S.Sams	S.Sams	S.Sams	S.Sams	S.Sams	S.Sams
32	209Y1A0246	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan
33	209Y1A0247	S.Shashi	S.Shashi	S.Shashi	S.Shashi	S.Shashi	S.Shaik	S.Shaik	S.Shaik	S.Shaik	S.Shaik
34	209Y1A0248	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed
35	209Y1A0249	Palle	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi
36	209Y1A0252	Jagan	Jagan	Jagan	Jagan	Jagan	Jagan	Jagan	Jagan	Jagan	Jagan
37	219Y5A0201	Nagu	Nagu	Nagu	Nagu	Nagu	Nagu	Nagu	Nagu	Nagu	Nagu
38	219Y5A0202	A.Venkata Yaswanth	A.Venkata Yaswanth	A.Venkata Yaswanth	A.Venkata Yaswanth	A.Venkata Yaswanth	A.Venkata Yaswanth	A.Venkata Yaswanth	A.Venkata Yaswanth	A.Venkata Yaswanth	A.Venkata Yaswanth
39	219Y5A0203	B.CH	B.CH	B.CH	B.CH	B.CH	B.CH	B.CH	B.CH	B.CH	B.CH
40	219Y5A0204	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai
41	219Y5A0205	M.Lakshmidevi	M.Lakshmidevi	M.Lakshmidevi	M.Lakshmidevi	M.Lakshmidevi	M.Lakshmidevi	M.Lakshmidevi	M.Lakshmidevi	M.Lakshmidevi	M.Lakshmidevi

Co-ordinator

H.O.D

HEAD
Department of Electrical & Electronics Engineering
K.S.R.M. College of Engineering
Kadapa -516003.

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Name of theEvent: Value Added Course on "Modern Control Systems" **Venue:SJ 105**

Attendance

SNo	Reg.No	6/12	7/12	8/12	9/12	10/12	12/12	13/12	14/12	15/12	16/12
1.	209Y1A0201	AGL	AGL	AGL	AGL	AGL	AGL	AGL	AGL	AGL	AGL
2.	209Y1A0202	AGa	AGa	AGai	AGai	AGa	A	AGa	AGa	AGa	AGa
3.	209Y1A0203	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana	Sanjana
4.	209Y1A0204	B@y	B@y	B@y	B@y	B@y	B@y	B@y	B@y	B@y	B@y
5.	209Y1A0206	C.R	C.R	C.R	C.R	C.R	C.R	C.R	C.R	C.R	C.R
6.	209Y1A0207	Sai Pavan	Sai Pavan	Sai Pavan	Sai Pavan	Sai Pavan	Sai Pavan	Sai Pavan	Sai Pavan	Sai Pavan	Sai Pavan
7	209Y1A0209	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani	Dhaani
8	209Y1A0210	D.L	D.L	D.L	D.L	D.L	D.L	D.L	D.L	D.L	D.L
9	209Y1A0211	G.H	G.H	G.H	G.H	G.H	G.H	G.H	A	G.H	G.H
10	209Y1A0213	G.V.S	G.V.S	G.V.S	G.V.S	G.V.S	G.V.S	G.V.S	G.V.S	G.V.S	G.V.S
11	209Y1A0216	Rahul	Rahul	Rahul	Rahul	Rahul	Rahul	Rahul	Rahul	Rahul	Rahul
12	209Y1A0217	K.L	K.L	K.L	K.L	K.L	K.L	K.L	K.L	K.L	K.L
13	209Y1A0218	Kavi	Kavi	Kavi	Kavi	Kavi	Kavi	Kavi	Kavi	Kavi	Kavi
14	209Y1A0220	KM	KM	KM	KM	KM	KM	KM	KM	KM	KM
15	209Y1A0221	K.Kiran	K.Kiran	K.Kiran	K.Kiran	K.Kiran	K.Kiran	K.Kiran	K.Kiran	K.Kiran	K.Kiran
16	209Y1A0222	saipavan	saipavan	saipavan	saipavan	saipavan	saipavan	saipavan	saipav	saipavan	saipavan
17	209Y1A0223	Gowri	Gowri	Gowri	Gowri	Gowri	Gowri	Gowri	Gowri	Gowri	Gowri
18	209Y1A0225	M.V	M.V	M.V	M.V	M.V	M.V	M.V	M.V	M.V	M.V
19	209Y1A0226	charan	charan	charan	charan	charan	charan	charan	charan	charan	charan
20	209Y1A0227	Maha	Maha	Maha	Maha	Maha	Maha	Maha	Maha	Maha	Maha
21	209Y1A0228	Pavan	Pavan	Pavan	Pavan	Pavan	Pavan	Pavan	Pavan	Pavan	Pavan

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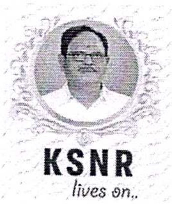

Name of theEvent: Value Added Course on "Modern Control Systems" **Venue:SJ 106**

Attendance

SNo	Reg.No	24/11	25/11	26/11	28/11	29/11	30/11	1/12	2/12	3/12	5/12
22	209Y1A0229	N.Sasi	A	N.Sasi	N.Sasi	N.Sasi	N.Sasi	N.Sasi	A	N.Sasi	N.Sasi
23	209Y1A0230	N.Alan	N.Alan	N.Alan	N.Alan	N.Alan	N.Alan	N.Alan	N.Alan	N.Alan	N.Alan
24	209Y1A0231	P.Yogi	P.Yogi	P.Yogi	P.Yogi	P.Yogi	P.Yogi	P.Yogi	P.Yogi	P.Yogi	P.Yogi
25	209Y1A0233	P.Raj	P.Raj	P.Raj	P.Raj	P.Raj	P.Raj	P.Raj	P.Raj	P.Raj	P.Raj
26	209Y1A0235	Sai vignesh	Sai vignesh	Sai vignesh	Sai vignesh	Sai vignesh	Sai vignesh	Sai vignesh	Sai vignesh	Sai vignesh	Sai vignesh
27	209Y1A0236	madhu lakshmi	madhu lakshmi	madhu lakshmi	madhu lakshmi	madhu lakshmi	madhu lakshmi	madhu lakshmi	madhu lakshmi	madhu lakshmi	madhu lakshmi
28	209Y1A0241	Alan	Alan	Alan	Alan	Alan	Alan	Alan	Alan	Alan	Alan
29	209Y1A0242	Sai	Sai	Sai	A	A	Sai	Sai	Sai	Sai	Sai
30	209Y1A0244	Shaik Sameer	Shaik Sameer	Shaik Sameer	Shaik Sameer	Shaik Sameer	Shaik Sameer	Shaik Sameer	Shaik Sameer	Shaik Sameer	Shaik Sameer
31	209Y1A0245	A.Samu	A.Samu	A.Samu	A.Samu	A.Samu	A.Samu	A.Samu	A.Samu	A.Samu	A.Samu
32	209Y1A0246	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan	S.Sudharshan
33	209Y1A0247	S.Shajid	S.Shajid	S.Shajid	S.Shajid	S.Shajid	S.Shajid	S.Shajid	S.Shajid	S.Shajid	S.Shajid
34	209Y1A0248	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed	S.Naveed
35	209Y1A0249	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi	Pallavi
36	209Y1A0252	Jagadesh	Jagadesh	Jagadesh	Jagadesh	Jagadesh	Jagadesh	Jagadesh	Jagadesh	Jagadesh	Jagadesh
37	219Y5A0201	Nagu	Nagu	Nagu	Nagu	Nagu	Nagu	Nagu	Nagu	Nagu	Nagu
38	219Y5A0202	A.Yash	A.Yash	A.Yash	A.Venkata Yaswanth	A.Venkata Yaswanth	A.Yash	A.Yash	A.Yash	A.Yash	A.Yash
39	219Y5A0203	B.C[illegible]	B.C[illegible]	B.C[illegible]	B.C[illegible]	B.C[illegible]	B.C[illegible]	B.C[illegible]	B.C[illegible]	B.C[illegible]	B.C[illegible]
40	219Y5A0204	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai	M.Sai
41	219Y5A0205	M.Lakshmi devi	M.Lakshmi devi	M.Lakshmi devi	M.Lakshmi devi	A	M.Lakshmi devi	M.Lakshmi devi	M.Lakshmi devi	M.Lakshmi devi	M.Lakshmi devi

Co-ordinator

H.O.D

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Electronics Engineering
K.S.R.M. College of Engineering
Kadapa -516003.

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Kadapa, Andhra Pradesh, India - 516 005
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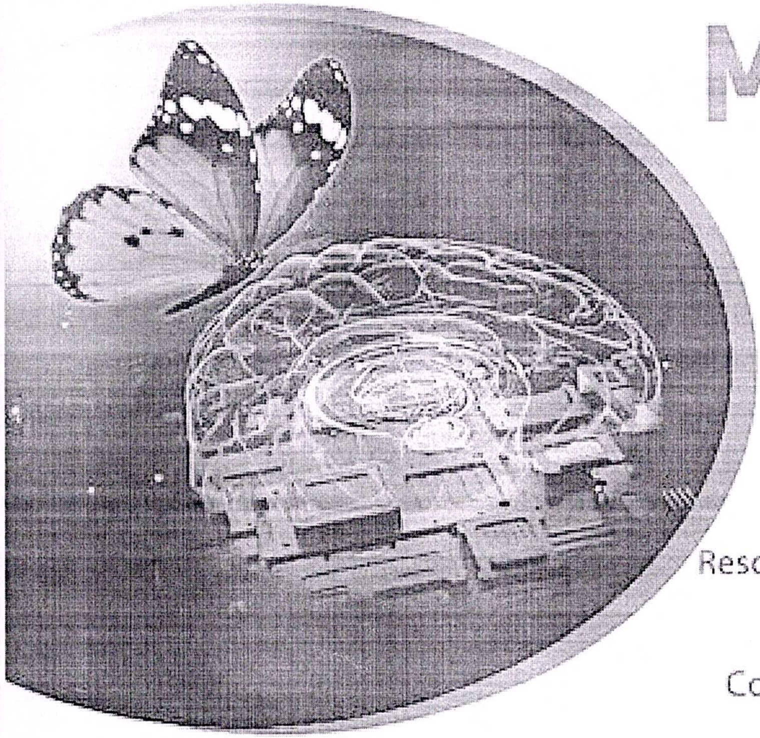
Value Added Course on
Modern Control Systems



Department of EEE

SJ106

24/11/2022 to 16/12/2022

Resource Persons Sri. K. Kalyan Kumar & Sri. N. Siddhik

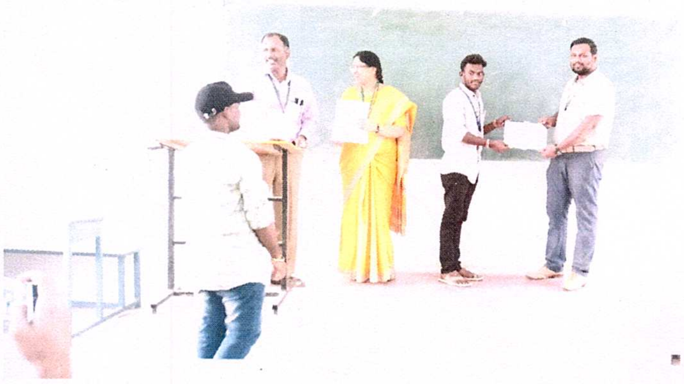
Coordinator Sri. T. Kishore Kumar

Department of Electrical and Electronics Engineering
Activity Report

Name of the Event	**Value Added Course**
Name of the Course	**MODERN CONTROL SYSTEMS**
Date(s)	24.11.2022 to 16.12.2022
Target Audience	B.Tech V Semester EEE Students
Number of Students Participated	41
Resource Persons	Mr. K. KALYAN KUMAR, Asst. Prof. in EEE, KSRMCE Mr. N. SIDDHIK, Asst. Prof. in EEE, KSRMCE
Organizer/Supporting Team	Mr. T. KISHORE KUMAR, Asst. Prof. in EEE, KSRMCE
Report	A total of 41 students registered from V Semester EEE and Mr. K. KALYAN KUMAR, Mr. N. SIDDHIK acted as resource persons. During the course the main topics covered are: • State space representation of a system. • Solution of state equations. • Controllability. • Observability. • Pole placement by state feedback. • State observers. • Liapunov Stability. The course was carried out for total 34hrs apart from the tentative schedule. At the end, Exam was conducted for the participants and at the valedictory ceremony they were awarded with the Course completion certificates.
Photos	 **HoD Addressing at valedictory of the course**

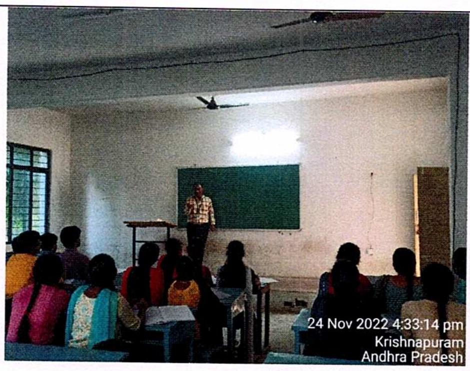
Distributing Course completion certificates to the students

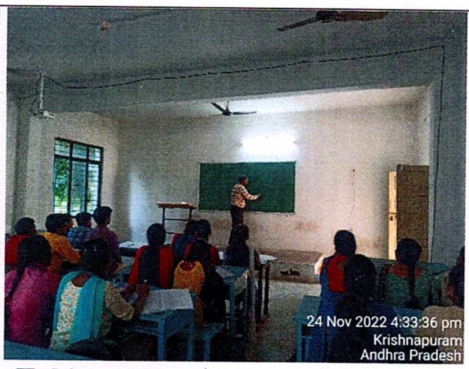
Distributing Course completion certificates to the students



Distributing Course completion certificates to the students

KSNR lives on..





Resource person Taking Classes

Exam Conducted to the Students

Coordinator

Head of the Department

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Kadapa, Andhra Pradesh,Indai-516003

LIGHTED TO LIGHTEN

Certificate of Completion

This is to certify that

K Venkata Sai

has successfully Completed the certification course on "**Modern Control Systems**" organized by the Department of Electrical & Electronics Engineering, KSRM College of Engineering(Autonomous), Kadapa from 24.11.2022 to 16.12.2022.

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Certificate of Completion

This is to certify that

L N Sai Pavan

*has successfully Completed the certification course on "**Modern Control Systems**" organized by the Department of Electrical & Electronics Engineering, KSRM College of Engineering(Autonomous), Kadapa from 24.11.2022 to 16.12.2022.*

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Certificate of Completion

This is to certify that

S Sudharshan

*has successfully Completed the certification course on "**Modern Control Systems**" organized by the Department of Electrical & Electronics Engineering, KSRM College of Engineering(Autonomous), Kadapa from 24.11.2022 to 16.12.2022.*

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Certificate of Completion

This is to certify that

K Hemanth Kumar

*has successfully Completed the certification course on "**Modern Control Systems**" organized by the Department of Electrical & Electronics Engineering, KSRM College of Engineering(Autonomous), Kadapa from 24.11.2022 to 16.12.2022.*

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Department of Electrical and Electronics Engineering

Date: 16.12.2022

Feedback

Name of the Student: M. Chandra Bharath kumar Reddy

Roll Number: 20941A0225

E-Mail ID: mcbkr26@gmail.com

Provide the following information:

1. Organization of Course and session planning by instructor?

   Excellent ✓ Very Good Good Average Poor

2. Clarity in content delivery?

   Excellent Very Good ✓ Good Average Poor

3. Content is relevant and useful?

   Excellent ✓ Very Good Good Average Poor

4. Adequate opportunity to interact with Resource Person?

   Excellent Very Good ✓ Good Average Poor

5. Overall rating?

   Excellent Very Good ✓ Good Average Poor

6. Any other Suggestions Nothing

M. CBKR

Signature of the Student

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Department of Electrical and Electronics Engineering

Date: 16.12.2022

Feedback

Name of the Student: G. Harika

Roll Number: 20941A0211

E-Mail ID: 20941A0211 @ ksrmce.ac.in

Provide the following information:

1. Organization of Course and session planning by instructor?

   Excellent | Very Good ✓ | Good | Average | Poor

2. Clarity in content delivery?

   Excellent | Very Good ✓ | Good | Average | Poor

3. Content is relevant and useful?

   Excellent | Very Good ✓ | Good | Average | Poor

4. Adequate opportunity to interact with Resource Person?

   Excellent | Very Good ✓ | Good | Average | Poor

5. Overall rating?

   Excellent | Very Good ✓ | Good | Average | Poor

6. Any other Suggestions

   No suggestions

G. Harika
Signature of the Student

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Department of Electrical and Electronics Engineering

Date: 16.12.2022

Feedback

Name of the Student: K. Likhitha

Roll Number: 209Y1A0217

E-Mail ID: 209Y1A0217 @ ksrmce.ac.in

Provide the following information:

1. Organization of Course and session planning by instructor?

   Excellent   Very Good   Good ✓   Average   Poor

2. Clarity in content delivery?

   Excellent   Very Good   Good ✓   Average   Poor

3. Content is relevant and useful?

   Excellent   Very Good   Good ✓   Average   Poor

4. Adequate opportunity to interact with Resource Person?

   Excellent   Very Good   Good ✓   Average   Poor

5. Overall rating?

   Excellent   Very Good   Good ✓   Average   Poor

6. Any other Suggestions

   No suggestions

K. Likhitha
Signature of the Student

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Department of Electrical and Electronics Engineering

Date: 16.12.2022

Feedback

Name of the Student: T. Pallavi

Roll Number: 209Y1A0249

E-Mail ID: 209Y1A0249@ksrmce.ac.in

Provide the following information:

1. Organization of Course and session planning by instructor?

   Excellent   ✓Very Good   Good   Average   Poor

2. Clarity in content delivery?

   Excellent   ✓Very Good   Good   Average   Poor

3. Content is relevant and useful?

   ✓Excellent   Very Good   Good   Average   Poor

4. Adequate opportunity to interact with Resource Person?

   Excellent   Very Good   ✓Good   Average   Poor

5. Overall rating?

   Excellent   Very Good   ✓Good   Average   Poor

6. Any other Suggestions

   No suggestions

T. Pal.

Signature of the Student

Department of Electrical and Electronics Engineering

Date: 16.12.2022

Feedback

Name of the Student: P. Ravi Shankar

Roll Number: 20941A0233

E-Mail ID: 20941A0233@ksrmce.ac.in

Provide the following information:

1. Organization of Course and session planning by instructor?

   Excellent　Very Good ✓　Good　Average　Poor

2. Clarity in content delivery?

   Excellent　Very Good　Good ✓　Average　Poor

3. Content is relevant and useful?

   Excellent　Very Good ✓　Good　Average　Poor

4. Adequate opportunity to interact with Resource Person?

   Excellent　Very Good ✓　Good　Average　Poor

5. Overall rating?

   Excellent　Very Good ✓　Good　Average　Poor

6. Any other Suggestions –

P. Ravi Shankar
Signature of the Student

K.S.R.M. COLLEGE OF ENGINEERING
(AUTONOMOUS)
Department of Electrical & Electronics Engineering
Feedback of students on Certification Course on "Printed Circuit Board"

S.No	Roll Number	Name of the Student	Organization of Course and session planning by instructor.	Clarity in content delivery.	Content is relevant and useful	Adequate opportunity to interact with Resource Person	Overall rating
1	209Y1A0201	A.Gopi Charan	Excellent	Excellent	Very good	Very good	Excellent
2	209Y1A0202	A.Gangadhar	Excellent	Very good	Excellent	Very good	Excellent
3	209Y1A0203	A Sanjana	Very good	Very good	Good	Very good	Excellent
4	209Y1A0207	D Sai Pavan	Excellent	Very good	Very good	Excellent	Excellent
5	209Y1A0204	B Neeraja Reddy	Good	Excellent	Very good	Very good	Excellent
6	209Y1A0206	C.Ramadevi	Good	Good	Very good	Good	Very good
7	209Y1A0209	D.Dharani	Very good	Very good	Excellent	Good	Good
8	209Y1A0210	D Tejaswini	Excellent	Excellent	Excellent	Excellent	Excellent
9	209Y1A0211	G Harika	Very good	Very good	Very good	Very good	Very good
10	209Y1A0213	G.V.Sunil Kumar	Very good	Very good	Very good	Very good	Very good
11	209Y1A0216	K Sai Rahul	Very good	Excellent	Excellent	Excellent	Excellent
12	209Y1A0217	K.Likhitha	Good	Good	Good	Good	Good
13	209Y1A0218	K.Md.Kaif Ali	Excellent	Excellent	Excellent	Excellent	Excellent
14	209Y1A0220	K Venkata Sai	Very good	Very good	Excellent	Very good	Excellent
15	209Y1A0221	K Hemanth Kumar	Fair	Excellent	Excellent	Excellent	Excellent
16	209Y1A0222	L N Sai Pavan	Excellent	Excellent	Excellent	Excellent	Excellent
17	209y1A0223	Madireddy Gowri	Very good	Very good	Excellent	Excellent	Excellent
18	209Y1A0225	Reddy	Very good	Excellent	Excellent	Very good	Excellent
19	209Y1A0226	M.Charan Kumar	Very good	Good	Very good	Very good	Excellent
20	209Y1A0227	M. Mahalakshmi	Excellent	Very good	Excellent	Very good	Excellent

21	209Y1A0228	M Pavan Kumar	Very good	Very good	Good	Excellent	Excellent
22	209Y1A0229	N.Sasi Rekha	Excellent	Excellent	Excellent	Excellent	Excellent
23	209Y1A0230	N Naveen Kumar	Excellent	Excellent	Excellent	Excellent	Excellent
24	209Y1A0231	P.Yogna	Excellent	Very good	Excellent	Excellent	Excellent
25	209Y1A0233	P.Ravi Shankar	Very good	Fair	Very good	Very good	Very good
26	209Y1A0235	Pothuraju Sai Vignesh	Good	Good	Good	Good	Good
27	209Y1A0236	R.Madhukrishna	Excellent	Excellent	Excellent	Excellent	Excellent
28	209Y1A0241	Shaik Alisha Sameera	Excellent	Excellent	Excellent	Excellent	Excellent
29	209Y1A0242	S Faiz Rehman	Excellent	Excellent	Very good	Very good	Excellent
30	209Y1A0244	S. Md. Sameer	Excellent	Very good	Excellent	Very good	Excellent
31	209Y1A0245	S.Parvez	Very good	Very good	Good	Very good	Excellent
32	209Y1A0246	S.Sudharshan	Excellent	Very good	Very good	Excellent	Excellent
33	209Y1A0247	S. Shashikala	Good	Excellent	Very good	Very good	Excellent
34	209Y1A0248	S Naveed	Good	Good	Very good	Good	Very good
35	209Y1A0249	T.Pallavi	Very good	Very good	Excellent	Good	Good
36	209Y1A0252	V Jagadeesh	Excellent	Excellent	Excellent	Excellent	Excellent
37	219Y5A0201	A.Nagarjuna	Very good	Very good	Very good	Very good	Very good
38	219Y5A0202	A. Venkata Yaswanth	Very good	Very good	Very good	Very good	Very good
39	219Y5A0203	Busagani Chandra Kumar	Excellent	Excellent	Excellent	Excellent	Excellent
40	219Y5A0204	M.Srinidhi	Very good	Very good	Very good	Very good	Very good
41	219Y5A0205	M.Lakshmi Devi	Very good	Very good	Very good	Very good	Very good

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
VALUE ADDED/CERTIFICATE COURSE ON
MODERN CONTROL SYSTEMS FROM 24/11/2022 TO 16/12/2022
AWARD LIST

S.No	Roll Number	Name of the Student	Marks Obtained
1	209Y1A0201	Abbarathi Gopi Charan	15
2	209Y1A0202	Adimulam Gangadhar	18
3	209Y1A0203	Ambavaram Sanjana (W)	17
4	209Y1A0204	Bandi Neeraja Reddy (W)	16
5	209Y1A0206	C Rama Devi (W)	18
6	209Y1A0207	Dasari Sai Pavan	17
7	209Y1A0209	Duggireddy Dharani (W)	16
8	209Y1A0210	Duggireddy Tejaswini (W)	18
9	209Y1A0211	Gaddam Harika (W)	19
10	209Y1A0213	G. Venkata Sunil Kumar	17
11	209Y1A0216	K. Sai Rahul	15
12	209Y1A0217	K. Likhitha (W)	19
13	209Y1A0218	K. Mohammed Kaif Ali	16
14	209Y1A0220	K. Venkata Sai	17
15	209Y1A0221	K. Hemanth Kumar	15
16	209Y1A0222	L. Narasimha Sai Pavan	17
17	209Y1A0223	M. Gowri (W)	17
18	209Y1A0225	M. Chandra Bharath Kumar Reddy	19
19	209Y1A0226	M.Charan Kumar	16
20	209Y1A0227	M. Maha Lakshmi (W)	19
21	209Y1A0228	M. Pavan Kumar	17
22	209Y1A0229	N. Sasi Rekha (W)	18
23	209Y1A0230	N. Naveen Kumar	17
24	209Y1A0231	P. Yogna (W)	16
25	209Y1A0233	P. Ravi Shankar	19
26	209Y1A0235	P. Sai Vignesh	18
27	209Y1A0236	R. Madhu Krishna	16

28	209Y1A0241	Shaik Alisha Sameera (W)	19
29	209Y1A0242	Shaik Faiz Rehman	15
30	209Y1A0244	Shaik Mohammed Sameer	15
31	209Y1A0245	Shaik Parvez	16
32	209Y1A0246	S. Sudharshan	16
33	209Y1A0247	S. Shashikala (W)	19
34	209Y1A0248	Syed Naveed	15
35	209Y1A0249	T. Pallavi (W)	16
36	209Y1A0252	Vema Jagadeesh	15
37	219Y5A0201	A. Nagarjuna	16
38	219Y5A0202	A.V. V. Yaswanth	17
39	219Y5A0203	B. Chandra Kumar	19
40	219Y5A0204	M. Srinidhi (W)	16
41	219Y5A0205	M. Lakshmi Devi (W)	17

Coordinator

HoD

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K.S.R.M. College of Engineering
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K.S.R.M. COLLEGE OF ENGINEERING (AUTONOMOUS), KADAPA-516005
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
VALUE ADDED /CERTIFICATE COURSE ON
MODERN CONTROL SYSTEMS FROM 24/11/2022 TO 16/12/2022
ASSESSMENT TEST

Roll Number: ________________ **Name of the Student:** ________________

Time: 20 Min **(Objective Questions)** **Max.Marks: 20**

Note: Answer the following Questions and each question carries one mark.

1. State variable approach of system analysis and design is applicable to [ ]
   A) Only linear time invariant (LTI) systems
   B) linear time invariant as well as time varying systems
   C) linear as well as nonlinear systems.
   D) All systems

2. By using the state variables, an n^{th} order differential equation can be decomposed into [ ]
   A) n number of first order differential equations
   B) 2n number of first order differential equations
   C) n/2 number of first order differential equations
   D) unlimited number of first order differential equations

3. Which of the following statement is true regarding the phase variables? [ ]
   A) The phase variables, in general, are the physical variables of the system
   B) The phase variables are readily available for measurement
   C) Phase variables are simple to realize mathematically
   D) Phase variables are practical set of state variables from control point of view

4. The Jordan canonical form of state model is applicable when [ ]
   A) All poles are real and distinct B) All poles are complex and distinct
   C) Some of the poles are real and some are repeated D) State model is not square

5. In which of the following state space representations decoupling of the state equations occur [ ]
   A) Observable Canonical B) Diagonal canonical C) Controllable canonical D) none of these

6. A non-singular 3x3 matrix [A] has 2, 3, and 5 as roots of its characteristic equation. The eigenvalues of the matrices [A] and its inverse A^{-1} will be respectively [ ]
   A) 1/2, 1/3, 1/5 and 2,3,5 B) 2,3,5 and 1/2, 1/3, 1/5
   C) both will have 2,3,5 D) both will have 1/2, 1/3, 1/5

7. The system matrix A is in controllable canonical form, then the diagonalizing or modal matrix of system matrix A can be called as [ ]
   A) State Transition Matrix B) Resolvant Matrix C) System Matrix D) Vander Monde Matrix

8. State Transition Matrix can be computed by [ ]
   A) Cayley Hamilton theorem B) Laplace Transform Method C) Expansion method D) All of these

9. Rank of matrix A $\begin{bmatrix} 5 & 0 & 0 \\ 2 & 1 & 0 \\ 0 & 2 & 3 \end{bmatrix}$ is

A) 3 B) 1 C) 2 D) 0

10. For the LTI system given by $\dot{x} = Ax$, the solution is given by

A) $X = e^{-At} X_0$ B) $X = e^{At} X_0$ C) $X_0 = e^{At} X$ D) none of these

11. For pole placement by state feedback, the system should be

A) Complete State controllable B) Complete State observable

C) have same eigen values D) have distinct eigen values

12. For the LTI system given by $\dot{x} = Ax + Bu, y = Cx$, if the desired [illegible] vector is dp then the feedback gain matrix is given by

A) K=acker(A,C,dp) B) K=acker(B,C,dp) C) K=acker(A,B,dp) D) None of these

13. For the system $\dot{x} = Ax + Bu, y = Cx$, if L is the desired full state observer [illegible] then for full state observer design, the required MATLAB command is

A) K=acker(A,C,L) B) K=acker(A',[illegible]) C) K=acker(A',[illegible]) D) [illegible] of these

14. Matrix |P|<0 implies

A) positive definiteness B) negative definiteness C) indefiniteness D) negative semi definiteness

15. Examine the controllability and observability of the LTI system given by

$$\dot{x} = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix} x + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u; y = [2 \quad 3] x$$

17

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
VALUE ADDED /CERTIFICATE COURSE ON
MODERN CONTROL SYSTEMS FROM 24/11/2022 TO 16/12/2022
ASSESSMENT TEST

Roll Number: 209Y1A0203 **Name of the Student:** A. Sanjana

Time: 20 Min **(Objective Questions)** **Max.Marks: 20**

Note: Answer the following Questions and each question carries **one** mark.

1. State variable approach of system analysis and design is applicable to [D]
   A) Only linear time invariant (LTI) systems
   B) linear time invariant as well as time varying systems
   C) linear as well as nonlinear systems.
   D) All systems

2. By using the state variables, an n^{th} order differential equation can be decomposed into [A]
   A) n number of first order differential equations
   B) 2n number of first order differential equations
   C) n/2 number of first order differential equations
   D) unlimited number of first order differential equations

3. Which of the following statement is true regarding the phase variables? [C]
   A) The phase variables, in general, are the physical variables of the system
   B) The phase variables are readily available for measurement
   C) Phase variables are simple to realize mathematically
   D) Phase variables are practical set of state variables from control point of view

4. The Jordan canonical form of state model is applicable when [C]
   A) All poles are real and distinct B) All poles are complex and distinct
   C) Some of the poles are real and some are repeated D) State model is not square

5. In which of the following state space representations decoupling of the state equations occur [B]
   A) Observable Canonical B) Diagonal canonical C) Controllable canonical D) none of these

6. A non-singular 3x3 matrix [A] has 2, 3, and 5 as roots of its characteristic equation. The eigenvalues of the matrices [A] and its inverse A^{-1} will be respectively [A]
   A) ½,1/3, 1/5 and 2,3,5 B) 2,3,5 and ½,1/3,1/5
   C) both will have 2,3,5 D) both will have ½,1/3,1/5

7. The system matrix A is in controllable canonical form, then the diagonalizing or modal matrix of system matrix A can be called as [D]
   A) State Transition Matrix B) Resolvant Matrix C) System Matrix D) Vander Monde Matrix

8. State Transition Matrix can be computed by [D]
   A) Cayley Hamilton theorem B) Laplace Transform Method C) Expansion method D) All of these

9. Rank of matrix A= $\begin{bmatrix} 5 & 0 & 0 \\ 2 & 1 & 0 \\ 0 & 2 & 3 \end{bmatrix}$ is [A]

A) 3 B) 1 C) 2 D) 0

10. For the LTI system given by $\dot{x} = Ax$, the solution is given by [B]

A) $X = e^{-At}X_0$ B) $X = e^{At}X_0$ C) $X_0 = e^{At}X$ D) none of these

11. For pole placement by state feedback, the system should be [A]

A) Complete State controllable B) Complete State observable

C) have same eigen values D) have distinct eigen values

12. For the LTI system given by $\dot{x} = Ax + Bu; y = Cx$. if the desired poles vector is dp then the feedback gain matrix is given by [C]

A) K=acker(A,C,dp) B) K=acker(B,C,dp) C) K=acker(A,B,dp) D) None of these

13. For the system $\dot{x} = Ax + Bu; y = Cx$, if L is the desired full state observer pole locations then for full state observer design, the required MATLAB command is [C]

A) K=acker(A,C,L) B) K=acker(A,C,L)' C) K=acker(A',C',L')' D) none of these

14. Matrix [P]<0 implies [A]

A) positive definiteness B) negative definiteness C) indefiniteness D) negative semi definiteness

15. Examine the controllability and observability of the LTI system given by

$$\dot{x} = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix} x + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u; y = [2 \quad 3]x$$

$A = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix}$

$B = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$

$C = \begin{bmatrix} 2 & 3 \end{bmatrix}$

5

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

det(Q_c) = 2 → rank = 2 [∵ n=2]

so, it is controllable

$Q_o = [C^T \quad A^T C^T] = \begin{bmatrix} 2 & 4 \\ 3 & 3 \end{bmatrix}$

det[Q_o] = -6

rank = 2

It is observability

(16)

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ASSESSMENT TEST

Roll Number: 209Y1A0204 **Name of the Student:** B. Neeraja Reddy.

Time: 20 Min **(Objective Questions)** **Max.Marks: 20**

Note: Answer the following Questions and each question carries **one** mark.

1. State variable approach of system analysis and design is applicable to [D]
   A) Only linear time invariant (LTI) systems
   B) linear time invariant as well as time varying systems
   C) linear as well as nonlinear systems.
   D) All systems

2. By using the state variables, an n^{th} order differential equation can be decomposed into [A]
   A) n number of first order differential equations
   B) 2n number of first order differential equations
   C) n/2 number of first order differential equations
   D) unlimited number of first order differential equations

3. Which of the following statement is true regarding the phase variables? [B]
   A) The phase variables, in general, are the physical variables of the system
   B) The phase variables are readily available for measurement
   C) Phase variables are simple to realize mathematically
   D) Phase variables are practical set of state variables from control point of view

4. The Jordan canonical form of state model is applicable when [C]
   A) All poles are real and distinct B) All poles are complex and distinct
   C) Some of the poles are real and some are repeated D) State model is not square

5. In which of the following state space representations decoupling of the state equations occur [B]
   A) Observable Canonical B) Diagonal canonical C) Controllable canonical D) none of these

6. A non-singular 3x3 matrix [A] has 2, 3, and 5 as roots of its characteristic equation. The eigenvalues of the matrices [A] and its inverse A^{-1} will be respectively [B]
   A) ½,1/3, 1/5 and 2,3,5 B) 2,3,5 and ½,1/3,1/5
   C) both will have 2,3,5 D) both will have ½,1/3,1/5

7. The system matrix A is in controllable canonical form, then the diagonalizing or modal matrix of system matrix A can be called as [A]
   A) State Transition Matrix B) Resolvant Matrix C) System Matrix D) Vander Monde Matrix

8. State Transition Matrix can be computed by [B]
   A) Cayley Hamilton theorem B) Laplace Transform Method C) Expansion method D) All of these

9. Rank of matrix A= $\begin{bmatrix} 5 & 0 & 0 \\ 2 & 1 & 0 \\ 0 & 2 & 3 \end{bmatrix}$ is [A]

A) 3 B) 1 C) 2 D) 0

10. For the LTI system given by $\dot{x} = Ax$, the solution is given by [B]

A) $X = e^{-At}X_0$ B) $X = e^{At}X_0$ C) $X_0 = e^{At}X$ D) none of these

11. For pole placement by state feedback, the system should be [A]

A) Complete State controllable B) Complete State observable

C) have same eigen values D) have distinct eigen values

12. For the LTI system given by $\dot{x} = Ax + Bu; y = Cx$, if the desired poles vector is dp then the feedback gain matrix is given by [B]

A) K=acker(A,C,dp) B) K=acker(B,C,dp) C) K=acker(A,B,dp) D) None of these

13. For the system $\dot{x} = Ax + Bu; y = Cx$, if L is the desired full state observer pole locations then for full state observer design, the required MATLAB command is [C]

A) K=acker(A,C,L) B) K=acker(A,C,L)' C) K=acker(A',C',L')' D) none of these

14. Matrix [P]<0 implies [B]

A) positive definiteness B) negative definiteness C) indefiniteness D) negative semi definiteness

15. Examine the controllability and observability of the LTI system given by

$$\dot{x} = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix} x + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u; y = [2 \;\; 3]x$$

$A = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix}$

$B = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$

$C = [2 \;\; 3]$

$\Rightarrow Q_C = [B \;\; AB] = \begin{bmatrix} 1 & 2 \\ 2 & 2 \end{bmatrix} \Rightarrow \det(Q_C) = -2$

Rank = 2

It is a controlability

$\Rightarrow Q_O = [C^T \;\; A^TC^T] = \begin{bmatrix} 2 & 3 \\ 3 & 3 \end{bmatrix}$

$\det(Q_O) = -6$

rank = 2 ($\because n = 2$)

It is a obserabiity.

6

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Roll Number: 209Y1A0209 **Name of the Student:** D. Dhavani

Time: 20 Min **(Objective Questions)** **Max.Marks: 20**

Note: Answer the following Questions and each question carries **one** mark.

1. State variable approach of system analysis and design is applicable to [D]
   A) Only linear time invariant (LTI) systems
   B) linear time invariant as well as time varying systems
   C) linear as well as nonlinear systems.
   D) All systems

2. By using the state variables, an n^{th} order differential equation can be decomposed into [A]
   A) n number of first order differential equations
   B) 2n number of first order differential equations
   C) n/2 number of first order differential equations
   D) unlimited number of first order differential equations

3. Which of the following statement is true regarding the phase variables? [B]
   A) The phase variables, in general, are the physical variables of the system
   B) The phase variables are readily available for measurement
   C) Phase variables are simple to realize mathematically
   D) Phase variables are practical set of state variables from control point of view

4. The Jordan canonical form of state model is applicable when [C]
   A) All poles are real and distinct B) All poles are complex and distinct
   C) Some of the poles are real and some are repeated D) State model is not square

5. In which of the following state space representations decoupling of the state equations occur [B]
   A) Observable Canonical B) Diagonal canonical C) Controllable canonical D) none of these

6. A non-singular 3x3 matrix [A] has 2, 3, and 5 as roots of its characteristic equation. The eigenvalues of the matrices [A] and its inverse A^{-1} will be respectively [B]
   A) ½,1/3, 1/5 and 2,3,5 B) 2,3,5 and ½,1/3,1/5
   C) both will have 2,3,5 D) both will have ½,1/3,1/5

7. The system matrix A is in controllable canonical form, then the diagonalizing or modal matrix of system matrix A can be called as [A]
   A) State Transition Matrix B) Resolvant Matrix C) System Matrix D) Vander Monde Matrix

8. State Transition Matrix can be computed by [B]
   A) Cayley Hamilton theorem B) Laplace Transform Method C) Expansion method D) All of these

9. Rank of matrix A= $\begin{bmatrix} 5 & 0 & 0 \\ 2 & 1 & 0 \\ 0 & 2 & 3 \end{bmatrix}$ is [A]

A) 3 B) 1 C) 2 D) 0

10. For the LTI system given by $\dot{x} = Ax$, the solution is given by [B]

A) $X = e^{-At}X_0$ B) $X = e^{At}X_0$ C) $X_0 = e^{At}X$ D) none of these

11. For pole placement by state feedback, the system should be [A]

A) Complete State controllable B) Complete State observable

C) have same eigen values D) have distinct eigen values

12. For the LTI system given by $\dot{x} = Ax + Bu; y = Cx$. if the desired poles vector is dp then the feedback gain matrix is given by [B]

A) K=acker(A,C,dp) B) K=acker(B,C,dp) C) K=acker(A,B,dp) D) None of these

13. For the system $\dot{x} = Ax + Bu; y = Cx$, if L is the desired full state observer pole locations then for full state observer design, the required MATLAB command is [C]

A) K=acker(A,C,L) B) K=acker(A,C,L)' C) K=acker(A',C',L')' D) none of these

14. Matrix [P]<0 implies [B]

A) positive definiteness B) negative definiteness C) indefiniteness D) negative semi definiteness

15. Examine the controllability and observability of the LTI system given by

$$\dot{x} = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix} x + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u; y = [2 \quad 3]x$$

Sol:- $A = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix}$

$B = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$

$C = \begin{bmatrix} 2 & 3 \end{bmatrix}$

6

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

$\det(Q_c) = -2$

rank = 2

so, it is controllable

$Q_o = [C^T \quad A^TC^T] = \begin{bmatrix} 2 & 4 \\ 3 & 3 \end{bmatrix}$

rank = 2 [∵ n = 2]

so it is observable

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Roll Number: 20941A0210 **Name of the Student:** D. Tejaswini

Time: 20 Min **(Objective Questions)** **Max.Marks: 20**

Note: Answer the following Questions and each question carries one mark.

1. State variable approach of system analysis and design is applicable to [D]
   A) Only linear time invariant (LTI) systems
   B) linear time invariant as well as time varying systems
   C) linear as well as nonlinear systems.
   D) All systems

2. By using the state variables, an n^{th} order differential equation can be decomposed into [A]
   A) n number of first order differential equations
   B) 2n number of first order differential equations
   C) n/2 number of first order differential equations
   D) unlimited number of first order differential equations

3. Which of the following statement is true regarding the phase variables? [C]
   A) The phase variables, in general, are the physical variables of the system
   B) The phase variables are readily available for measurement
   C) Phase variables are simple to realize mathematically
   D) Phase variables are practical set of state variables from control point of view

4. The Jordan canonical form of state model is applicable when [B]
   A) All poles are real and distinct B) All poles are complex and distinct
   C) Some of the poles are real and some are repeated D) State model is not square

5. In which of the following state space representations decoupling of the state equations occur [C]
   A) Observable Canonical B) Diagonal canonical C) Controllable canonical D) none of these

6. A non-singular 3x3 matrix [A] has 2, 3, and 5 as roots of its characteristic equation. The eigenvalues of the matrices [A] and its inverse A^{-1} will be respectively [B]
   A) ½,1/3, 1/5 and 2,3,5 B) 2,3,5 and ½,1/3,1/5
   C) both will have 2,3,5 D) both will have ½,1/3,1/5

7. The system matrix A is in controllable canonical form, then the diagonalizing or modal matrix of system matrix A can be called as [D]
   A) State Transition Matrix B) Resolvant Matrix C) System Matrix D) Vander Monde Matrix

8. State Transition Matrix can be computed by [D]
   A) Cayley Hamilton theorem B) Laplace Transform Method C) Expansion method D) All of these

9. Rank of matrix A= $\begin{bmatrix} 5 & 0 & 0 \\ 2 & 1 & 0 \\ 0 & 2 & 3 \end{bmatrix}$ is [A]

A) 3 B) 1 C) 2 D) 0

10. For the LTI system given by $\dot{x} = Ax$, the solution is given by [B]

A) $X = e^{-At}X_0$ B) $X = e^{At}X_0$ C) $X_0 = e^{At}X$ D) none of these

11. For pole placement by state feedback, the system should be [A]

A) Complete State controllable B) Complete State observable

C) have same eigen values D) have distinct eigen values

12. For the LTI system given by $\dot{x} = Ax + Bu; y = Cx$, if the desired poles vector is dp then the feedback gain matrix is given by [C]

A) K=acker(A,C,dp) B) K=acker(B,C,dp) C) K=acker(A,B,dp) D) None of these

13. For the system $\dot{x} = Ax + Bu; y = Cx$, if L is the desired full state observer pole locations then for full state observer design, the required MATLAB command is [C]

A) K=acker(A,C,L) B) K=acker(A,C,L)' C) K=acker(A',C',L')' D) none of these

14. Matrix [P]<0 implies [B]

A) positive definiteness B) negative definiteness C) indefiniteness D) negative semi definiteness

15. Examine the controllability and observability of the LTI system given by

$$\dot{x} = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix} x + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u; y = [2 \ \ 3]x$$

$A = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix}$

$B = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$

$C = \begin{bmatrix} 2 & 3 \end{bmatrix}$

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

$\det(Q_c) = -2 \Rightarrow$ rank $= 2$ $[\because n=2]$

6

so, it is controllable

$Q_o = [C^T \ A^T C^T] = \begin{bmatrix} 2 & 4 \\ 3 & 3 \end{bmatrix}$

$\det[Q_o] = -6$

rank $= 2$ $[\because n=2]$

It is a observable

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Roll Number: 209Y1A0231 **Name of the Student:** P. Yogna.

Time: 20 Min **(Objective Questions)** **Max.Marks: 20**

Note: Answer the following Questions and each question carries **one** mark.

1. State variable approach of system analysis and design is applicable to [D]
   A) Only linear time invariant (LTI) systems
   B) linear time invariant as well as time varying systems
   C) linear as well as nonlinear systems.
   D) All systems

2. By using the state variables, an n^{th} order differential equation can be decomposed into [a]
   A) n number of first order differential equations
   B) 2n number of first order differential equations
   C) n/2 number of first order differential equations
   D) unlimited number of first order differential equations

3. Which of the following statement is true regarding the phase variables? [b] b
   A) The phase variables, in general, are the physical variables of the system
   B) The phase variables are readily available for measurement
   C) Phase variables are simple to realize mathematically
   D) Phase variables are practical set of state variables from control point of view

4. The Jordan canonical form of state model is applicable when [a] b
   A) All poles are real and distinct B) All poles are complex and distinct
   C) Some of the poles are real and some are repeated D) State model is not square

5. In which of the following state space representations decoupling of the state equations occur [c] b
   A) Observable Canonical B) Diagonal canonical C) Controllable canonical D) none of these

6. A non-singular 3x3 matrix [A] has 2, 3, and 5 as roots of its characteristic equation. The eigenvalues of the matrices [A] and its inverse A^{-1} will be respectively [d] b
   A) ½,1/3, 1/5 and 2,3,5 B) 2,3,5 and ½,1/3,1/5
   C) both will have 2,3,5 D) both will have ½,1/3,1/5

7. The system matrix A is in controllable canonical form, then the diagonalizing or modal matrix of system matrix A can be called as [d]
   A) State Transition Matrix B) Resolvant Matrix C) System Matrix D) Vander Monde Matrix

8. State Transition Matrix can be computed by [d]
   A) Cayley Hamilton theorem B) Laplace Transform Method C) Expansion method D) All of these

9. Rank of matrix A= $\begin{bmatrix} 5 & 0 & 0 \\ 2 & 1 & 0 \\ 0 & 2 & 3 \end{bmatrix}$ is [a]

A) 3 B) 1 C) 2 D) 0

10. For the LTI system given by $\dot{x} = Ax$, the solution is given by [b]

A) $X = e^{-At}X_0$ B) $X = e^{At}X_0$ C) $X_0 = e^{At}X$ D) none of these

11. For pole placement by state feedback, the system should be [a]

A) Complete State controllable B) Complete State observable
C) have same eigen values D) have distinct eigen values

12. For the LTI system given by $\dot{x} = Ax + Bu; y = Cx$, if the desired poles vector is dp then the feedback gain matrix is given by [c]

A) K=acker(A,C,dp) B) K=acker(B,C,dp) C) K=acker(A,B,dp) D) None of these

13. For the system $\dot{x} = Ax + Bu; y = Cx$, if L is the desired full state observer pole locations then for full state observer design, the required MATLAB command is [c]

A) K=acker(A,C,L) B) K=acker(A,C,L)' C) K=acker(A',C',L')' D) none of these

14. Matrix [P]<0 implies [b]

A) positive definiteness B) negative definiteness C) indefiniteness D) negative semi definiteness

15. Examine the controllability and observability of the LTI system given by

$$\dot{x} = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix} x + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u; y = [2 \ \ 3]x$$

$A = \begin{bmatrix} 2 & 0 \\ 0 & 1 \end{bmatrix}$ $B = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$, $C = [2, 3]$

$Q_c = (B \ \ AB)$

$= \begin{bmatrix} 1 & 2 \\ 2 & 2 \end{bmatrix}$

$\det(Q_c) = -2 \Rightarrow$ rank $= 2$

So, it is controllable.

$Q_o = [C^T \ \ A^T C^T] = \begin{bmatrix} 2 & 4 \\ 3 & 3 \end{bmatrix}$

$\det(Q_o) = -6$

rank $= 2$

So system is observable.

UNIT-I

STATE VARIABLE DESCRIPTION

1.1 Limitations of conventional Control theory:

The main disadvantage of conventional control theory is that, it is applicable for the linear time invarient systems having single input and single output (SISO). It is poweeless for the time varing systems, non linear systems and milti input multi output systems (MIMO).

1.1.1 A New Approach To Control System Analysis and Design Modern Control Theory:

the Modern trend in engineering systems is towards greater comlexity due to the requirement of complex tasks and good accuracy. Complex systems may have MIMO and may be time varient because of the necessity of meeting the requirements of the control systems, the increase in system complexity and easy access to large scale computers leads to the modern control theory which is a new approach to the analysis and design of complex systems. This new approach is base on the concept of state.

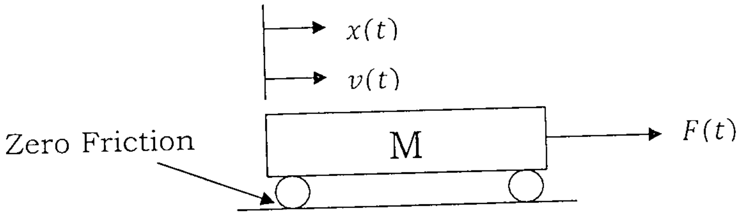
1.1.2 Modern Control Versus Conventional Control Theory:

1. Modern control theory is applicable for MIMO systems which may be a linear or nonlinear, time variant or time invariant.
2. Conventional control theory is applicable for only linear time invariant SISO systems.
3. MCT is essentially a time domain approach while convention control theory is complex frequency domain approach.
4. System design in classical control theory is based on trial and error procedures which in general will not yield optimal systems.
5. Design in MCT can be carried out for a class of the input, instead of a specific input function such as the impulse function, step function or sinusoidal function and includes initial conditions in the design concept.

1.2 Concept of State:

A mathematical idea to represent the dynamics of a system utilizes three types of variables called the input, output and state variables.

Consider the mechanical system as shown below with a mass element.



$$M\frac{d^2x}{dt^2} = F(t)$$

$$\frac{d^2x}{dt^2} = \frac{1}{M}F(t)$$

$$\frac{dv}{dt} = \frac{1}{M}F(t) \quad since \ \frac{dx}{dt} = v(t)$$

From this relatoion we get

$$v(t) = \frac{1}{M}\int_{-\infty}^{t} F(t)\,dt$$

$$= \frac{1}{M}\int_{-\infty}^{t_0} F(t)\,dt + \frac{1}{M}\int_{t_0}^{t} F(t)dt$$

$$v(t) = v(t_0) + \frac{1}{M}\int_{t_0}^{t} F(t)dt$$

$$x(t) = \int_{-\infty}^{t} v(t)dt$$

$$= \int_{-\infty}^{t_0} v(t)\,dt + \int_{t_0}^{t} v(t)dt$$

$$= x(t_0) + \int_{t_0}^{t} v(t_0)dt + \frac{1}{M}\int_{t_0}^{t} d\tau \int_{t_0}^{t} F(t)dt$$

$$x(t) = x(t_0) + (t - t_0)\,v(t_0) + \frac{1}{M}\int_{t_0}^{t} d\tau \int_{t_0}^{t} F(t)dt$$

The displacement $x(t)$ at any time $t \geq t_0$ can be computed if we know the aplied force $f(t)$ from $F(t)$ from $t = t_0$ onwards, provided $v(t_0)$ the initial velcity and $x(t_0)$ the initial displacement are known. We may conceive of initial velocity and initial displacement as describeding the state of the system at $t = t_0$.

Let us look for the defination of state and state variables.

" *The state of a dynamic system is a set of minimal set of state variables such that the knowledge of these variables at* $t = t_0$ *togeather with the knowledge of the input for* $t \geq t_0$, *completely determines the behaviour of the system for* $t \geq t_0$."

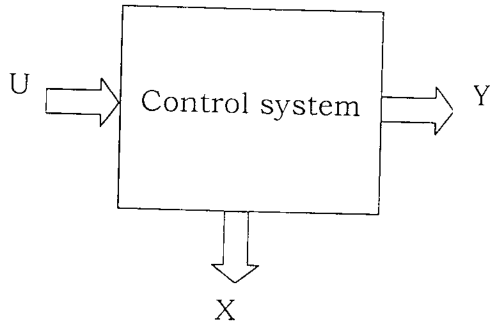
In state variables formation of the system

The state variables are represented by $x_1(t), x_2(t), \ldots\ldots\ldots\ldots, x_n(t)$.

The input variables are represented by $u_1(t), u_2(t), \dots\dots\dots\dots, u_m(t)$.

The state variables are represented by $y_1(t), y_2(t), \dots\dots\dots\dots, y_p(t)$.

The state space representation is represented in block diagram.



For this system the state representation can be arranged in the form of n first order differential equations.

$$\frac{dx_1}{dt} = \dot{x_1} = f_1(x_1(t), x_2(t), \dots\dots\dots\dots, x_n(t); u_1(t), u_2(t), \dots\dots\dots\dots, u_m(t))$$

. . . .

. . . .

$$\frac{dx_n}{dt} = \dot{x_n} = f_n(x_1(t), x_2(t), \dots\dots\dots\dots, x_n(t); u_1(t), u_2(t), \dots\dots\dots\dots, u_m(t))$$

The n differential equations may be written in vector notation as

$$\dot{X(t)} = f(X(t), U(t))$$

The above equation is called state equation

From the figure $y(t)$ can be expressed in terms of state $x(t)$ and $u(t)$ as

$$Y(t) = g(X(t), U(t))$$

This equation is called output equation

This state equation and output equation combine called as state model of the system.

1.3 State Model:

State model of a linear time invariant system is given below as follow.

$$\dot{x_1} = a_{11}x_1 + a_{12}x_2 + \cdots \dots\dots\dots + a_{1n}x_n + b_{11}u_1 + b_{12}u_2 \dots\dots\dots\dots + b_{1m}u_m$$

$$\dot{x_2} = a_{21}x_1 + a_{22}x_2 + \cdots \dots\dots\dots + a_{2n}x_n + b_{21}u_1 + b_{22}u_2 \dots\dots\dots\dots + b_{2m}u_m$$

. . . .

$$\dot{x_n} = a_{n1}x_1 + a_{n2}x_2 + \cdots \dots\dots\dots + a_{nn}x_n + b_{n1}u_1 + b_{n2}u_2 \dots\dots\dots\dots + b_{nm}u_m$$

In vector notation $\dot{X}(t) = AX(t) + BU(t)$

Where

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ . & . & & . \\ . & . & & . \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$ Which is a $n \times n$ matrix

$$B = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1m} \\ b_{21} & b_{22} & \cdots & b_{2m} \\ . & . & & . \\ . & . & & . \\ b_{n1} & b_{n2} & \cdots & b_{nm} \end{bmatrix}$$ Which is a $n \times m$ matrix

Similarly, the output variables

$$y_1 = c_{11}x_1 + c_{12}x_2 + \cdots \dots \dots \dots \dots + c_{1n}x_n + d_{11}u_1 + d_{12}u_2 \dots \dots \dots \dots \dots + d_{1m}u_m$$
$$y_2 = c_{21}x_1 + c_{22}x_2 + \cdots \dots \dots \dots \dots + c_{2n}x_n + d_{21}u_1 + d_{22}u_2 \dots \dots \dots \dots \dots + d_{2m}u_m$$
$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad .$$
$$y_p = c_{p1}x_1 + c_{p2}x_2 + \cdots \dots \dots \dots \dots + c_{pn}x_n + d_{p1}u_1 + d_{p2}u_2 \dots \dots \dots \dots \dots + d_{pm}u_m$$

In vector notation $Y(t) = CX(t) + DU(t)$

Where

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ . & . & & . \\ . & . & & . \\ c_{p1} & c_{p2} & \cdots & c_{pn} \end{bmatrix}$$ Which is a $p \times n$ matrix

$$D = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1m} \\ d_{21} & d_{22} & \cdots & d_{2m} \\ . & . & & . \\ d_{p1} & d_{p2} & \cdots & d_{pm} \end{bmatrix}$$ Which is a $p \times m$ matrix

The state model of linear time- invariant system is thus given by

$$\dot{X}(t) = AX(t) + BU(t)$$

$$Y(t) = CX(t) + DU(t)$$

For the system which is considered, let us define

$$x = x_1$$

$$v = \dot{x} = x_2$$

$$u = F$$

$$\dot{x_2} = \frac{1}{M} F = \frac{1}{M} u$$

$$\dot{x_1} = x_2$$

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{M} \end{bmatrix} u \quad \text{------- State equation}$$

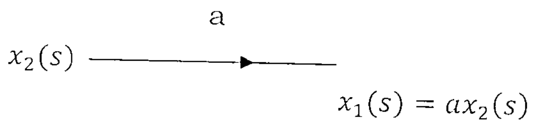
$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \quad \text{---------------- Output equation}$$

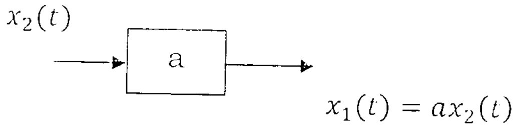
1.4 State Diagram:

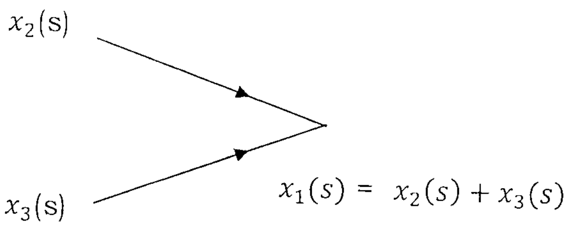
The pictorial representation of the state model of the system is called state diagram. The important significance of the state model of the state diagram is that it forms a closer relationship among the state models, differential equations and computer simulation.

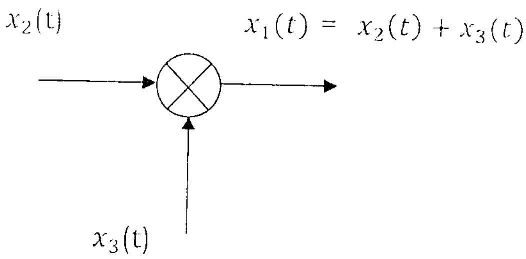
The state diagram of a state model is constructed by using three basic units. Scalars, Adders and Integrators.

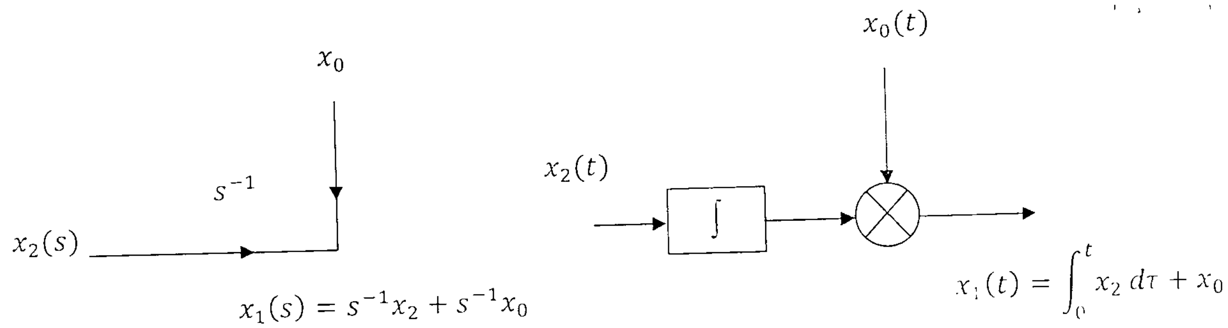
The signal flow graph and the block diagram representation with the use of the basic units are given below







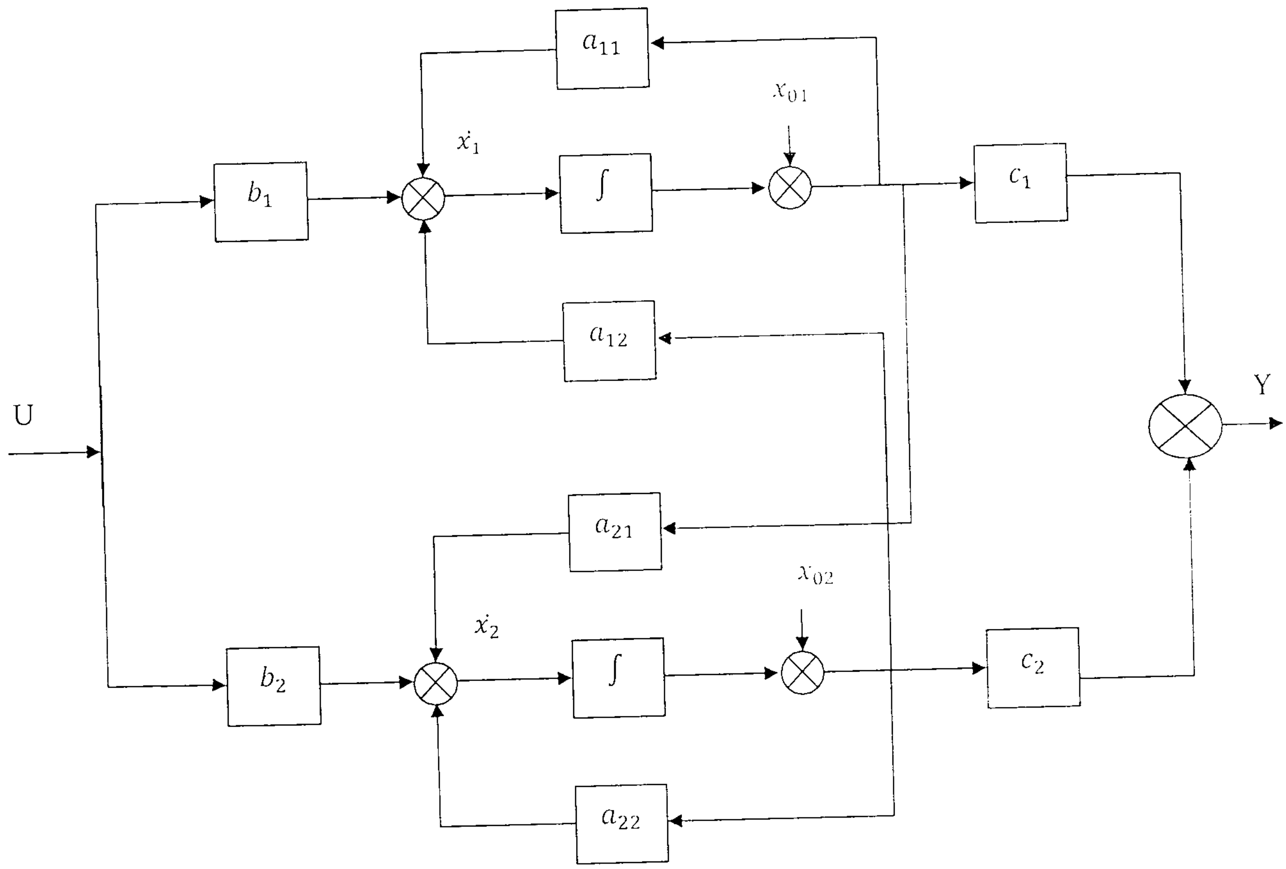




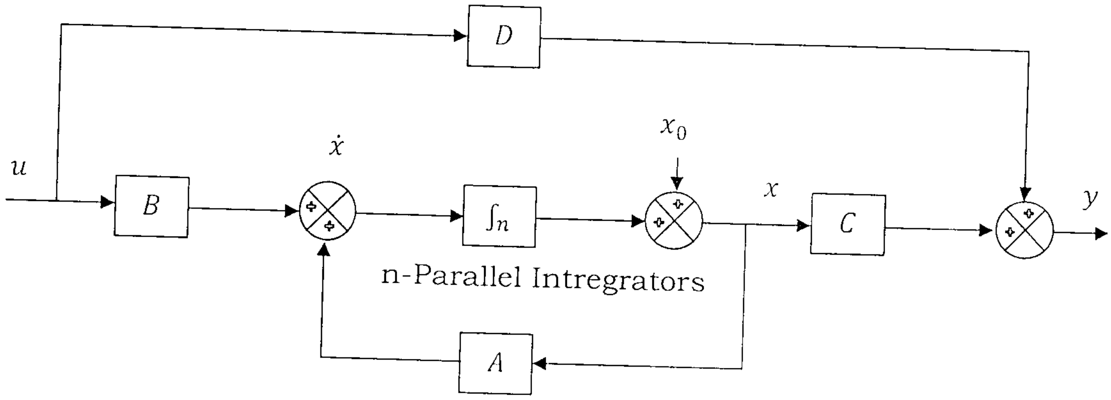
Consider the system with a single input $u(t)$ single output $y(t)$ and two state variables x_1 *and* x_2. The system equations are

$$\dot{x_1} = a_{11}x_1 + a_{12}x_2 + b_1u \; ; \; x_1(0) = x_{01}$$
$$\dot{x_2} = a_{21}x_1 + a_{22}x_2 + b_2u \; ; \; x_2(0) = x_{02}$$
$$y = c_1x_1 + c_2x_2$$

The state diagram for this set of equations utilizing two integrators



This procedure can be easily extended for a MIMO system with n state variables. The general philosophy of the state diagram for the multivariable system can be expressed graphically as

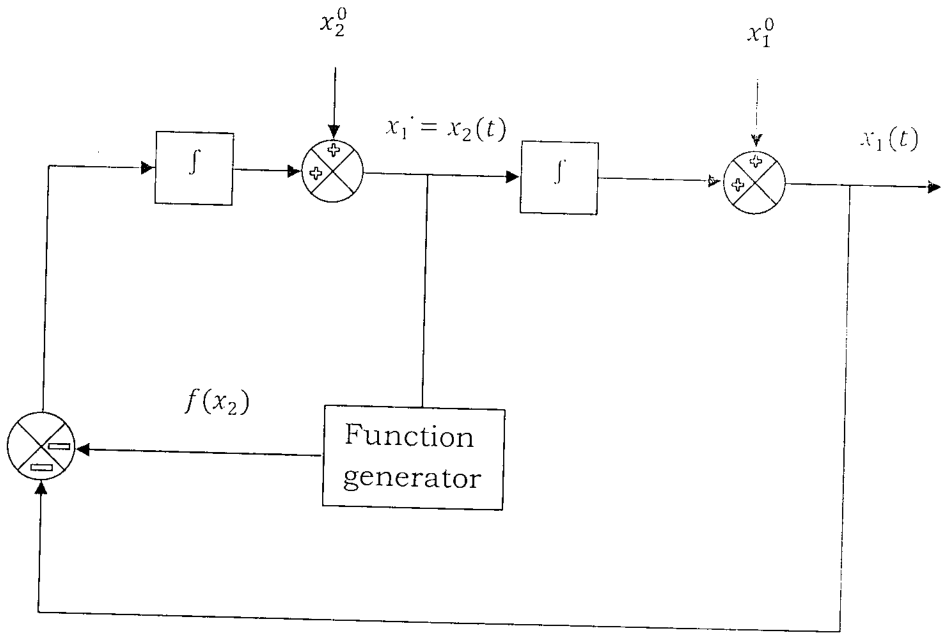


For nonlinear time varying state models, the state diagram cannot be obtained in terms of the three basic units-scalars, adders, integrators. In addition to these, we require non linear function generators and time dependent devices. Consider for example, the state model

$$\dot{x}_1(t) = x_2(t); \qquad x_1(0) = x_1^0$$

$$\dot{x}_2(t) = -x_1(t) - f(x_2(t)); \qquad x_2(0) = x_2^0$$

Where $f(x_2)$ is a nonlinear function of x_2. below figure shows the state diagram for this system



1.5 Solution of State Equations

The Solution of the state equation for which the system transient response can be obtained. Let us first review the classical method of solution by considering a first order scalar differential equation.

$$\frac{dx}{dt} = ax \, ; x(0) = x_0$$

This equation has the solution

$$x(t) = e^{at} x_0$$
$$= \left(1 + at + \frac{1}{2!}a^2t^2 + \cdots + \frac{1}{i!}a^it^i + \cdots\right)x_0$$

Let us now consider the state equation

$$\dot{X}(t) = A\,X(t);\; X(0) = X_0 \quad (1)$$

Which represents the homogeneous linear system with constant coefficients.

By analogy with the scalar case, we assume a solution of the form

$$X(t) = a_0 + a_1t + a_2t^2 + \cdots + a_it^i + \cdots$$

Where are Vector coefficients.

By substituting the assumed solution in equation (1) we get

$$a_1 + 2a_2t^1 + 3a_3t^2 + \cdots = A(a_0 + a_1t + a_2t^2 + \cdots + a_it^i + \cdots)$$

On comparing the coefficients

$$a_1 = \mathrm{A}a_0$$
$$a_2 = \frac{1}{2}\mathrm{A}a_1 = \frac{1}{2!}\mathrm{A}^2a_0$$
$$a_i = \frac{1}{i!}\mathrm{A}^ia_0$$

In the assumed solution, equating $X(t{=}0){=}X_0$, we find that

$$a_0 = X_0$$

The solution $X(t)$ is found to be

$$X(t) = (I + At + \frac{1}{2!}A^2t^2 + \cdots + \frac{1}{i!}A^it^i + \cdots)X_0$$

Each term inside the term bracket is an $n \times n$ matrix. We call it as ***matrix exponential method*** which my written as

$$e^{At} = I + At + \frac{1}{2!}A^2t^2 + \cdots + \frac{1}{i!}A^it^i + \cdots$$

The solution now can be written as

$$\boxed{X(t) = e^{At}X_0}$$

e^{At} is known as ***state transition matrix*** and is denoted by $\varphi(t)$

Let us now determine the solution for the non-homogeneous state equation

$$\dot{X}(t) = A X(t) + Bu(t);\ X(0) = X_0$$

Rewriting the equation in the form

$$\dot{X}(t) - A X(t) = Bu(t)$$

Multiplying both sides by e^{-At}, we can write $e^{-At}[\dot{X}(t) - A X(t)] = \frac{d}{dt} e^{-At}x(t)$

Integrating both sides with respect to t between the limits 0 to t we get

$$\int_0^t e^{-At}x(t)\ dt = \int_0^t e^{-A\tau}Bu(\tau)d\tau$$

$$e^{-At}\mathrm{x}(t) - \mathrm{x}(0) = \int_0^t e^{-A\tau}Bu(\tau)d\tau$$

Now pre multiplying both sides by e^{At}, we have

$$X(t) = e^{At}X_0 + \int_{t_0}^{t} e^{A(t-\tau)}Bu(\tau)d\tau$$

Properties of State Transition Matrix

In the above discussion the state Transition Matrix has been defined as

$$\varphi(t) = e^{At}$$

The useful properties of STM are as follows:

1. $\varphi(0) = e^{At} = I$
2. $\varphi(t)^{-1} = \varphi(-t)$
3. $\varphi(t_1 + t_2) = \varphi(t_1)\varphi(t_2)$

1.6 Computation of STM

1.6.1 Computation by Laplace Transformation:

Let us consider the unforced equation whose state equation is

$$\dot{X}(t) = A X(t)$$

Taking the Laplace transformation of this equation, we obtain

$$sX(s) - X(0) = AX(s)$$

$$sX(s) - AX(s) = X(0)$$

$$[s\mathbf{I} - A]X(s) = X(0)$$

$$X(s) = [s\mathbf{I} - A]^{-1}X(0)$$

Taking inverse Laplace transformation, we get

$$X(t) = L^{-1}\{ [s\mathbf{I} - A]^{-1} \}X(0)$$

The comparison yields a different approach to determine the STM which is given below:

$$\varphi(0) = e^{At} = L^{-1}\{ [s\mathbf{I} - A]^{-1} \} = L^{-1}\{ \varphi(s) \}$$

Where $\varphi(s) = [s\mathbf{I} - A]^{-1}$ is called ***resolvent matrix***

Let us consider the force equation whose state equation is

$$\dot{X}(t) = A\,X(t) + Bu(t)$$

Performing the Laplace transformation gives

$$sX(s) - X(0) = AX(s) + BU(s)$$

$$[sI - A]X(s) = X(0) + BU(s)$$

$$X(s) = \{[sI - A]^{-1}\}X(0) + \{[sI - A]^{-1}BU(s)\}$$

By Inverse Laplace transformation

$$X(t) = L^{-1}\{[sI - A]^{-1}\}X(0) + L^{-1}\{[sI - A]^{-1}BU(s)\}$$

$$X(t) = \{\varphi(t)\}X(0) + L^{-1}\{\varphi(s)BU(s)\}$$

1.6.2 Computation by Cayley-Hamilton Therem:

The state transition matrix may be computed using the technique based on the Cayley-Hamilton Theorem. For large systems this method is more convenient computationally as compared to the other two methods advanced earlier. To begin with let us start the Cayley-Hamilton Theorem.

Every square matrix A satisfies its own characteristic equation. In other words, if

$$q(\lambda) = |\lambda I - A| = \lambda^n + a_1\lambda^{n-1} + \cdots + a_{n-1}\lambda^1 + a_n = 0 \qquad (1)$$

Is the characteristic equation of A, then

$$q(A) = A^n + a_1A^{n-1} + \cdots + a_{n-1}A^1 + a_nI = 0 \qquad (2)$$

This theorem provides a simple procedure for evaluating the function of the matrix. In the study of linear systems, we are mostly concerned which can be represented as a series of the power of a matrix. Given an $n \times n$ matrix A with the characteristic equation as in equation (1),let the Eigen values of A. The matrix polynomial

$$f(A) = k_0\boldsymbol{I} + k_1\boldsymbol{A} + k_2\boldsymbol{A}^2 + \cdots + k_n\boldsymbol{A}^n + k_{n+1}\boldsymbol{A}^{n+1} + \cdots \quad (3)$$

Can be computed by considering the scalar polynomial

$$f(\lambda) = k_0 + k_1\lambda + k_2\lambda^2 + \cdots + k_n\lambda^n + k_{n+1}\lambda^{n+1} + \cdots \quad (4)$$

If $f(\lambda)$ is divided by the characteristic polynomial $q(\lambda)$ then we have

$$\frac{f(\lambda)}{q(\lambda)} = \boldsymbol{Q}(\lambda) + \frac{R(\lambda)}{q(\lambda)}$$

Or $$f(\lambda) = \boldsymbol{Q}(\lambda)q(\lambda) + R(\lambda) \quad (5)$$

Where $R(\lambda)$ is the remainder polynomial of the following form:

$$R(\lambda) = \alpha_0 + \alpha_1\lambda + \alpha_2\lambda^2 + \cdots + \alpha_{n-1}\lambda^{n-1} \quad (6)$$

If we evaluate $f(\lambda)$ at the eigen values $\lambda_1, \lambda_2, \ldots\ldots\ldots\ldots \lambda_n$; then $q(\lambda) = 0$and we have

$$f(\lambda_i) = R(\lambda_i)\ i = 1,2, \ldots\ldots\ldots\ldots, n \quad (7)$$

The coefficients $\alpha_0, \alpha_1, \ldots\ldots\ldots, \alpha_{n-1}$ can be obtained by successively substituting $\lambda_1, \lambda_2, \ldots\ldots\ldots\ldots \lambda_n$ in equation (7) substituting A for the variable λ in equation (5), we get

$$f(A) = \boldsymbol{Q}(A)q(A) + R(A)$$

Since $q(A)$ is ideally zero, it follows that

$$f(A) = R(\boldsymbol{A})$$

$$= \alpha_0\boldsymbol{I} + \alpha_1\boldsymbol{A} + \cdots + \alpha_{n-1}\boldsymbol{A}^{n-1} \quad (8)$$

Which is the desired result.

Procedure to evaluate the matrix:

1. Find the eigenvalues
2. Write the polynomial $R(\lambda)$and evaluate coefficients $\alpha_0, \alpha_1, \ldots. \alpha_{n-1}$ by substituting obtained eigenvalues in $R(\lambda)$
3. Find the $f(A)$ by the equation $f(A) = \alpha_0\boldsymbol{I} + \alpha_1\boldsymbol{A} + \cdots + \alpha_{n-1}\boldsymbol{A}^{n-1}$.

PROBLEMS

1. Obtain The STM for the State Model whose **A** Matrix is given by

   $a)\ A = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$ $b)\ A = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix}$ $c)\ A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$ $d)\ A = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$

2. Obtain The STM for the State Model whose **A** Matrix is given by using Cayley-Hamilton theorem.

   $a)\ A = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$ $b)\ A = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix}$ $c)\ A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$

3. Find $f(A) = A^{10}$ for

   $a)\ A = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix}$ $b)\ A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$

4. Find $f(A) = e^{At}$ for

   $A = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix}$