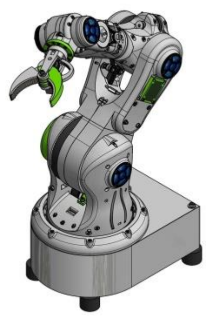
MUZAFFARPUR INSTITUTE OF TECHNOLOGY (MIT), MUZAFFARPUR

COURSE FILE

OF

MODERN CONTROL THEORY

(EE 031815)



Faculty Name: Dr. N Kumar

ASSISTANT PROFESSOR,

DEPARTMENT OF ELECTRICAL ENGINEERING

विज्ञान एवं प्रावैधिकी विभाग

Department of Science and Technology

Government of Bihar

CONTENTS

VISION STATEMENT OF ELECTRICAL ENGINEERING DEPARTMENT

To produce cutting edge Electrical Engineers, innovators, researchers, and entrepreneurs with high human values to serve society, industry, nation and the world.

MISSION STATEMENT OF ELECTRICAL ENGINEERING DEPARTMENT

M1. To create state-of-the-art facilities for under-graduate, post- graduate and R&D work.

M2. To cater the needs of society with recent technologies, innovative ideas and inculcate ethical responsibilities.

M3. To develop strong collaborative links with premier industries, institutions and the government agencies.

Program Educational Objectives (PEOs) of Electrical Engineering Department:

PEO 1. Students will be able to engage in life-long learning and research including supportive and responsible roles on multi-disciplinary tasks.

PEO 2. Students will acquire, use and develop skills as required for effective professional and societal practices and leadership quality.

PEO 3. Students will be able to create a new dimension of innovation and entrepreneurship.

Program Outcomes (POs) based on Program Educational Objectives (PEOs) of Electrical Engineering Department:

PO 1. Students will be able to apply knowledge of applied mathematics & science in electrical engineering problems.

PO 2. Students will be able to identify, formulate and solve society and industries related problems.

PO 3. Students will be able to apply knowledge to design a system, component or process to meet desired needs within realistic constraints.

PO 4. Students will be able to conduct laboratory experiments and to critically analyze and interpret experimental data.

PO 5. Students will be able to use the recent techniques, skills, and modern tools necessary for engineering practices.

PO 6. Students will be able to understand the impact of engineering problems, solutions in a global and societal context.

PO 7. Students will be able to demonstrate professional and ethical responsibilities.

PO 8. Students will be able to apply leadership quality to work with team in the area of electrical engineering towards the solution of multi-disciplinary tasks.

PO 9. Students will be able to communicate effectively through verbally, technical writing, reports and presentation.

PO 10. Students will be able to develop confidence for self-education and ability to engage in life-long learning.

Course Description

This course is designed to learn about the control of complex systems with multiple inputs and outputs through state space modeling. The course is designed such that the student will appreciate the relationship of transfer function in conventional control and state space equations in modern control systems. Student will learn the method of controlling the non-linear systems too.

Course Objectives

1. Students will be able to identify the modern control
2. Students will be able to differentiate between controllability and observability of state variables
3. Students will be able to design a control system for a given plant
4. Student will be able to analyze the stability of a control system
5. Student will be able to using MATLAB

Course Outcomes

CO 1. Ability to express control system models on state space models

CO 2. Ability to express state transition matrix and calculation of variables.

CO 3. The concepts of controllability and observability.

CO 4. Ability to design control system and optimal control system

CO 5. Ability to apply nonlinear control system and phase pane method

CO-PO MAPPING

Sr. No.	Course Outcome	PO
CO 1.	Ability to express control system models on state space models	PO1-PO4,PO7,PO8,PO9
CO 2.	Ability to express state transition matrix and calculation of variables.	PO1-PO4,PO8
CO 3.	The concepts of controllability and observability	PO1-PO4,PO10
CO 4.	Ability to design control system and optimal control system	PO1- PO4,PO7,PO8,PO10
CO 5.	Ability to apply nonlinear control system and phase pane method	PO1, PO2, PO3,PO6,PO10

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO 1. Ability to express control system models on state space models		√	√				√		√	
CO 2. Ability to express state transition matrix and calculation of variables		√	√	√				√		
CO 3. The concepts of controllability and observability.			√	√						√
CO 4. Ability to design control system and optimal control system		√	√	√			√	√		√
CO5 Ability to apply nonlinear control system and phase pane method		√	√			√				√

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B. Tech. VIII Semester (EE)

EE-031815 (MODERN CONTROL THEORY)

L T P/D Total	Max Marks:	100	
3-1-0 4		Final Exam:	70 Marks
		Sessional:	20 Marks
		Internals:	10 Marks.

UNIT-I

Development of state space model, state and state equation, transfer function from state equation and state equation from transfer function.

UNIT-II

State transient matrix, solution of state equation transfer matrix.

UNIT-III

Concept of controllability and absorbability

UNIT-IV

State variable feedback, state observes.

UNIT-V

Control system design via pole placement

UNIT-VI

Optimal control system introduction, performance in device, transfer function approach, state variable approach, parameter optimization

UNIT-VII

Non-liner system common non-liner stability system, method for studying non-liner system, linearization, describing function analysis.

UNIT-VIII

The phase plane method stability analysis using Lyapunov's direct method

Books:

1 Modern Control by Ogata, Pearson Education

2 Control Engineering: Theory & Practice by Bandopadhya, PHI

8th Semester EEE							
Period	**I**	**II**	**III**		**IV**	**V**	**VI**
Day/ time	**10:00-11:00**	**11:00-12:00**	**12:00-01:00**	**01:00-01:30**	**01:30-02:30**	**02:30-03:30**	**03:30-04:30**
MON		**MCT**		**LUNCH BREAK**			
TUE	**MCT**						
WED							
THU		**MCT**					
FRI							
SAT	**MCT**						
MCT – MODERN CONTROL THEORY (031815) - ROOM NO. 112							

Student List

S. No.	Roll No	Name of Students
1	13E17	NEERAJ KUMAR
2	14E43	SHOAA AKBARI
3	14E01	AYUSH KUMAR
4	14E02	ANSHU PRIYA
5	14E05	ABHISHEK
6	14E06	UDIT KUMAR
7	14E07	NEHA KUMARI
8	14E08	DEEPAK KUMAR
9	14E09	NAVENDU JHA
10	14E10	VIKASH KUMAR
11	14E11	PANKAJ KUMAR RAMAN
12	14E12	KUMAR AYUSH
13	14E13	ADITYA KUMAR
14	14E14	SUDHAKAR PRASAD
15	14E15	SHWETA KUMARI
16	14E17	PAMIT KUMAR
17	14E19	MD SHAH JAHAN
18	14E20	CHANDAN PRAKASH
19	14E21	ASHUTOSH KUMAR
20	14E23	SHALU KUMARI
21	14E24	KANHAIYA LAL MANDAL
22	14E28	SURYA KANT PATEL

23	14E30	**GULSHAN KUMAR**
24	14E31	**ARVIND KUMAR**
25	14E32	**SATISH KUMAR SINGH**
26	14E33	**AVINASH KUMAR**
27	14E34	**RANJIT KUMAR**
28	14E35	**RAVI RANJAN**
29	14E36	**ABHISHEK KUMAR**
30	14E38	**ALAKH NIRANJAN KUMAR**
31	14E39	**KAMLESH KUMAR**
32	14E40	**DHARAMVEER KUMAR**
33	14E44	**NITESH**
34	14E47	**BHAWNA SINHA**
35	14E18	**DEEP SHIKHA**
36	14E22	**ANURANJAN KUMAR**
37	14E25	**DEEPAK KUMAR**
38	14E41	**ABHISHEK RAJ**
39	14E42	**RAVINDAR KUMAR**
40	14E45	**KAMLESH KUMAR**
41	14E46	**CHANDAN KUMAR**
42	14E48	**AHMAD RAJA**
43	14E16	**LAVANYA**
44	14E54	**RAVI KANT SINGH**
45	14E51	**NIDHI**
46	14E52	**ROHIT**
47	14E53	**KUMARI PALLAVI**
48	14E55	**PRASHANT KUMAR**
49	14E58	**MD NAHID ALAM**

50	14E59	**PRINCE KUMAR**
51	14E60	**MANI RAJ**
52	14E62	**ALEKH RAJ**
53	14E63	**SURAJ KUMAR**
54	14E56	**RAJAN KUMAR**
55	14E61	**PANKAJ KUMAR SAW**
56	15(LE)E05	**SARITA KUMARI**
57	15(LE)E06	**PRATIBHA KUMARI**
58	15(LE)E01	**VICKEY KUMAR**
59	15(LE)E03	**ANAND KUMAR**
60	15(LE)E04	**SONAM SINHA**
61	15(LE)E07	**ABHISHEK KUMAR**
62	15(LE)E08	**ASHUTOSH KUMAR**

Institute / School Name :	Muzaffarpur Institute of Technology (MIT), Muzaffarpur		
Program Name	**B.Tech. EE**		
Course Code	031815		
Course Name	MODERN CONTROL THEORY		
Lecture / Tutorial (per week):	3/1	**Course Credits**	4
Course Coordinator Name	Dr. N Kumar		

1. Scope and Objectives of the Course

Scope: This course is designed to learn about the control of complex systems with multiple inputs and outputs through state space modelling. The course is designed such that the student will appreciate the relationship of transfer function in conventional control and state space equations in modern control systems. Student will learn the method of controlling the non-linear systems too.

Objectives:

1. Students will be able to identify the modern control
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3. Students will be able to design a control system for a given plant
4. Student will be able to analyze the stability of a control system
5. Student will be able to using MATLAB

The course outcomes are:

1. Ability to express control system models on state space models

2. Ability to express state transition matrix and calculation of variables.

3 .The concepts of controllability and observability.

4. Ability to design control system and optimal control system

5. Ability to apply nonlinear control system and phase pane method

2. Textbooks

TB1: 'Modern Control by Ogata, 5th Pearson Education

Reference Books

RB1: ' Control Engineering: Theory & Practice by Bandopadhya, PHI

Other readings and relevant websites

S.No.	**Link of Journals, Magazines, websites and Research Papers**
1.	http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-011-introduction-to-communication-control-and-signal-processing-spring-2010/http://mirror.mit-ocw.sbu.ac.ir/courses/civil-and-environmental-engineering/1-72-groundwater-hydrology-fall-2005/lecture-notes/
2.	http://nptel.ac.in/courses/108103007/

3. Course Plan

Lecture Number	Date of Lecture	Topics	**Web Links for video lectures**	**Text Book / Reference Book / Other reading material**	**Page numbers of Text Book(s)**
1-5		Development of state space model		TB1	88-94,765-775
		State and state equation, transfer function from state equation and state equation from transfer function			
Tutorial – 1, Assignment I					
6-10		**State transient matrix**		TB1	776-790
		Solution of state equation transfer matrix			

Tutorial – 2, Assignment II					
11-16		**Controllability and Observability.**		TB1	791-803
		Concept of controllability and observability, state variable feedback			
Tutorial - 3, Assignment III					
17-19		**Control system design**		TB1, RB1	838-921
		Control system design via pole placement; , state observer			
Tutorial – 4, , Assignment IV					
20-25		**Optimal control system**		RB1	362-454
		Introduction, performance in device, transfer function approach, state variable approach, parameter optimization			
Tutorial - 5, Assignment V					
Mid-Semester Exam (Syllabus covered from 1-25 lectures)					
26-33		**Non-linear system**		RB1	255-267
		Common non-liner			

		stability system, method for studying non-liner system, linearization, describing function analysis			
Tutorial 6, Assignment VI					
34-38		**The phase pane method**		RB1	268-288
		Stability analysis using Lyapunov's direct method			
Tutorial - 7, Assignment VII					

1. **Evaluation Scheme:**

Component 1*	Sessional Test (ST)*	20
Component 2	Assignment Evaluation	10
Component 3**	End Term Examination**	70
	Total	**100**

SYLLABUS

Topics	No of lectures	Weightage
State and state equation, transfer function from state equation and state equation from transfer function.	5	13%
State transient matrix, solution of state equation transfer matrix	5	13%
Concept of controllability and observability, State variable feedback.	6	16%
Control system design via pole placement; state observer	3	8%
Optimal control system: Introduction, performance in device, transfer function approach, state variable approach, parameter optimization.	6	16%

Non-liner system: common non-liner stability system, method for studying non-liner system, linearization, describing function analysis.	8	21%
The phase plane method: Stability analysis using Lyapunov's direct method.	5	13%

This Document is approved by:

Designation	**Name**	**Signature**
Course Coordinator	Dr. N Kumar	
H.O.D	DR. YAGYANAND SHARMA	
Dean	DR. JAGNANAND JHA	
Date	22-06-2018	

Evaluation and Examination Blue Print:

Internal assessment is done through quiz tests, presentations, assignments and project work. Two sets of question papers are asked from each faculty and out of these two, without the knowledge of faculty, one question paper is chosen for the concerned examination. The components of evaluations along with their weightage followed by the University is given below

Sessional Test 20%

Internals 10%

End term examination 70%

Institute / School Name :	Muzaffarpur Institute of Technology (MIT), Muzaffarpur		
Program Name	**B.Tech. EE**		
Course Code	031815		
Course Name	MODERN CONTROL THEORY		
Lecture / Tutorial (per week):	3/1	**Course Credits**	4
Course Coordinator Name	Dr. N Kumar		

LECTURE PLAN

Topics	**Lecture Number**	**Date on which the Lecture was taken**
Development of state space model		
Introduction	**1**	
State and state equation,	**2**	
transfer function from state equation	**3**	
state equation from transfer function	**4-5**	
State transient matrix		
Introduction	**6**	
Solution of state equation transfer matrix	**7-10**	
Controllability and Observability.		
Introduction,	**11**	
Concept of controllability	**11-13**	
Observability, state variable feedback	**13-16**	
Control system design		
Control system design via pole placement	**17-18**	
state observer	**18-19**	
Optimal control system		
Introduction,	**20**	
performance in device,	**21**	
transfer function approach,	**22**	

Department of EE
MODERN CONTROL THEORY

<u>Assignment I</u>

1. Derive a state space model for the system shown Fig.-1

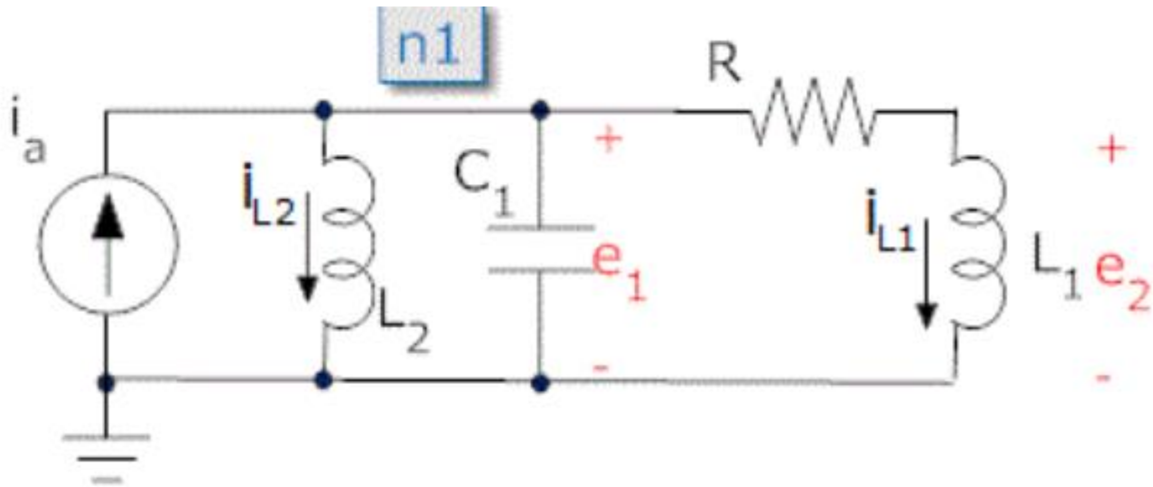


Fig. (a)

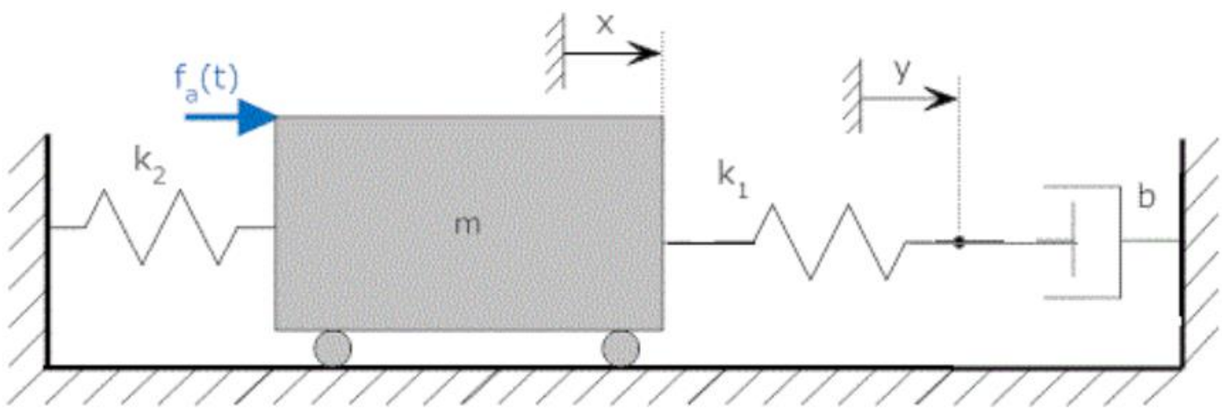


Fig. (b)

2. Explain the property of the nonlinear systems.

3. With neat sketches explain (1) on-off controller, (2.) backlash, (3.) saturation, (4) singular point,(5) stability in the sense of liapunov, (6) asymptotic stability and (7) Instability, (8) jump response

4. Explain the delta method of obtaining the phase tranjectories.

5. Prove that ATp+pA=-Q for linear time invariant system.

6. Explain the concept of controllability and observability, with the condition for complete controllability and observability in the S- plane.

7. Write short notes on

(a) Pole placement by state feedback.

(b) state transition matrix

(c) MIMO systems

(d) Principle of duality due to kalman

8. Obtain a state space representation of the system

$$\frac{C(s)}{U(s)} = \frac{10(s+2)}{s^3+3s^2+5s+15}$$

9. Discuss the state controllability of the system

$$\begin{bmatrix} \dot{X}_1 \\ \dot{X}_2 \end{bmatrix} = \begin{bmatrix} -3 & 1 \\ -2 & 1.5 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 4 \end{bmatrix} u$$

Prove the conditions used.

10. Explain controllability and observability.

11. Define state of a system, state variables, state space and state vector. What are the advantages of state space analysis?

12. State liapunov stability theorems.

13. Given the procedural step of constructing phase trajectories using isoclines method.

Tutorial Sheet

1. **Obtain the state space model for a system characterized by the following differential equation**

$$\dddot{y} + 6\ddot{y} + 5\dot{y} + y = u$$

Draw a block diagram using the state space model.

2. Obtain the state model of the given network shown in Figure 1, in the standard form.
R_1 = **1W, C_1 = 1** f **,** R_2 = **2W, C_2 = 1** f **,** R_3 = **3W. Choose voltage across capacitor** C_1 **as** e_1 **and voltage across capacitor** C_2 **as** e_2 **as state variables.**

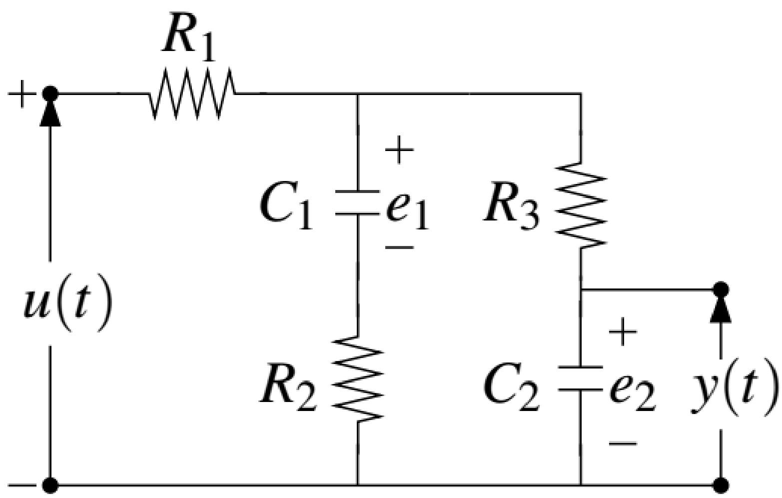


Figure 1:

3. Obtain the state model of the given electrical system shown in Figure 2, choosing $x_1(t) = i(t)$ **and** $x_2(t) = v_o(t)$**, where** $x_1(t)$ **and** $x_2(t)$ **are state variables.**

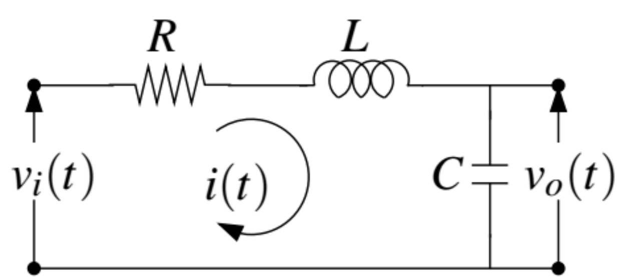


Figure 2:

3. Obtain a state-space representation of the system shown in Figure 3, where R **and** D **are the inputs and** Y **is the output.**

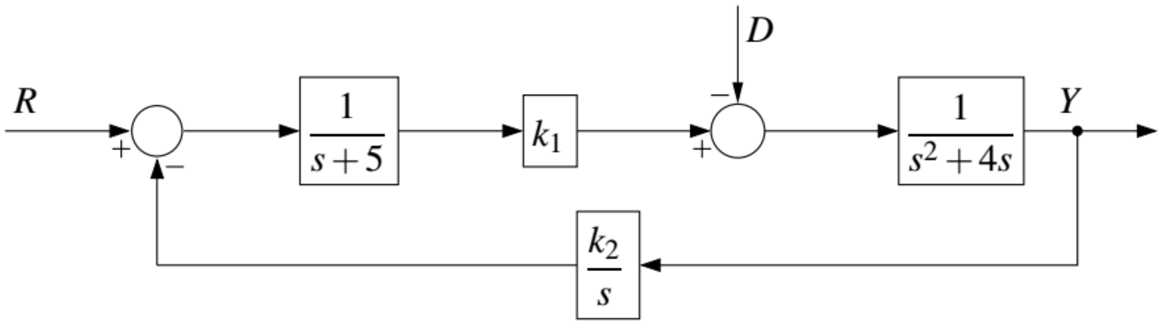
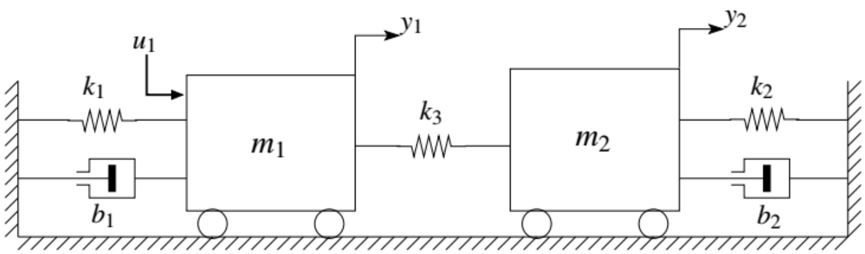


Figure 3:

4. Obtain a state-space representation of the mechanical system shown in Figure , where u1 is the input and y1 and y2 are the outputs.



6. Consider the system given by

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

For this case,

$$[\mathbf{B} \vdots \mathbf{AB}] = \begin{bmatrix} 0 & 1 \\ 1 & -1 \end{bmatrix} = \text{nonsingular}$$

The system is therefore completely state controllable.

7. Consider the system described by:

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

$$y = [1 \quad 0] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

Is this system controllable and observable?

8. Consider the system defined by

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

Show that the system cannot be stabilized by the state-feedback control scheme

$$u=-Kx$$

whatever matrix K is chosen. (Notice that this system is not state controllable.)

Muzaffarpur Institute of Technology (MIT), Muzaffarpur

Mid-Semester (UG) Examinations, 2018

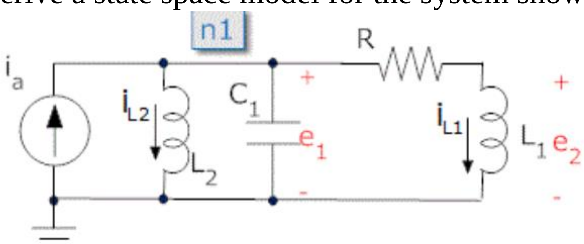
Subject Code: EE031609 | **Subject: MCT**
Semester: 8th | **Department: Electrical Engg.**
Duration: 2 Hrs. | **Total marks: 20**

Instructions:

(i) The marks are indicated in the right hand margin.
(ii) There are **Six** questions in this paper.
(iii) Attempt **Four** questions in all.

Answer the following questions

1. Derive a state space model for the system shown Fig. **5**



2. Explain controllability. **5**
3. Define state of a system, state variables, state space and state vector. **5**
4. Explain the concept of observability. **5**
5. Obtain a state space representation of the system **5**

$$\frac{C(s)}{U(s)} = \frac{10(s+2)}{s^3+3s^2+5s+15}$$

6 What are the advantages of state space analysis. **5**

Code : 031815

B.Tech. 8th Semester Exam., 2017

Modern Control Theory

Time : 3 hours *Full Marks : 70*

Instructions :

(i) The marks are indicated in the right-hand margin.

*(ii) There are **NINE** questions in this paper.*

*(iii) Attempt **FIVE** questions in all.*

(iv) Questions No. 1 is compulsory.

1. Answer any seven questions of the following: 2×7=14

(a) What are the drawbacks in transfer function model analysis?

(b) What is state and state variable?

(c) What is the need for state observer?

(d) Explain Eigen vector.

(e) What is pole placement by state feedback?

(f) Explain backlash.

(g) Write any two properties of eigenvalues.

(h) What is a dominant pole?

(i) What are phase variables?

(j) What is state observer?

P.T.O.

2. (a) Derive the solution of homogeneous state equations. 7

(b) Draw the state variable diagram for the given transfer function. 7

$$\frac{C(s)}{R(s)} = \frac{5s}{3s^2 + 3s + 1}$$

3. (a) A system is characterize by the transfer function.

$$\frac{Y(s)}{U(s)} = \frac{s+2}{s^3 + 3s^2 + 2s + 10}$$ 7

Find the state and output equations.

(b) A system is described by the equations as 7

$$\dot{x}(t) = \begin{bmatrix} -1 & 1 \\ 0 & 2 \end{bmatrix} x(t) + \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 2 \\ 1 & 0 \\ 1 & 1 \end{bmatrix} x(t)$$

Determine the transfer function.

4. Define controllability and observability. Comment on observability and controllability of the system described by the following state variable model. 14

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -6 & -5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

$$y(t) = [2 \;\; 1] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

5. (a) Define the describing function. Derive the describing function for backlash or relay with dead zone. 8

(b) Discuss the stability analysis with describing function. 6

6. Write the properties of state transition matrices. Compute e^{At} when. 14

$$A = \begin{bmatrix} 0 & 1 \\ -3 & -4 \end{bmatrix}$$

7. Given the plant G(s) = 20(s+5)/s(s+1)(s+2), design the phase variable feedback gains to yield 9.5% overshoot and a settling time of 0.74 second. 14

8. (a) Discuss common non-linearities present in a system. 7

(b) Discuss the state variable approach for optimal control problem. 7

9. Write short notes on any two of the following. 2×7

a. Liapunov's stability analysis
b. State observer design
c. Stability from phase plane
d. Dead-zone

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Name of Faculty:- N Kumar Branch:-EE

Course Code:- EE031815 Section:-8th sem.

Date of exam:-

Test Type:- Mid sem.

Test Abbrevation:mid sem

Maximum Marks 30

Test Topic:-MCT

Sr	Roll No.	Marks
1	13E17	25
2	14E43	26
3	14E01	26
4	14E02	26
5	14E05	27
6	14E06	27
7	14E07	28
8	14E08	27
9	14E09	25
10	14E10	26
11	14E11	26
12	14E12	25
13	14E13	26
14	14E14	27
15	14E15	26
16	14E17	26
17	14E19	27
18	14E20	26
19	14E21	19
20	14E23	27
21	14E24	26
22	14E28	26
23	14E30	28
24	14E31	25
25	14E32	28
26	14E33	25
27	14E34	26
28	14E35	27
29	14E36	26
30	14E38	28
31	14E39	27

32	14E40	27
33	14E44	26
34	14E47	26
35	14E18	24
36	14E22	26
37	14E25	23
38	14E41	27
39	14E42	22
40	14E45	27
41	14E46	27
42	14E48	24
43	14E16	24
44	14E54	27
45	14E51	26
46	14E52	26
47	14E53	24
48	14E55	25
49	14E58	25
50	14E59	25
51	14E60	24
52	14E62	23
53	14E63	23
54	14E56	26
55	14E61	21
56	15(LE)E05	25
57	15(LE)E06	25
58	15(LE)E01	24
59	15(LE)E03	25
60	15(LE)E04	26
61	15(LE)E07	24
62	15(LE)E08	25

RESULT ANALYSIS