Ref No:

< Sri Krishna Institute of Technology, Bangalore>

LABORATORY PLAN

Academic Year -2018- 19

Program:	B E – Electrical and Electronics Engineering
Semester :	6
Course Code:	15EEL67
Course Title:	Control System Laboratory
Credit / L-T-P:	2 / 0-0-2
Total Contact Hours:	42
Course Plan Author:	Shravanthi A

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Academic Evaluation and Monitoring Cell

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INSTRUCTIONS TO TEACHERS

- Classroom / Lab activity shall be started after taking attendance.
- Attendance shall only be signed in the classroom by students.
- Three hours attendance should be given to each Lab.
- Use only Blue or Black Pen to fill the attendance.
- Attendance shall be updated on-line & status discussed in DUGC.
- No attendance should be added to late comers.
- Modification of any attendance, over writings, etc is strictly prohibited.
- Updated register is to be brought to every academic review meeting as per the COE.

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Table of Contents

Note : Remove “Table of Content” before including in CP Book
Each Laboratory Plan shall be printed and made into a book with cover page
Blooms Level in all sections match with A.2, only if you plan to teach / learn at higher levels

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A. LABORATORY INFORMATION

1. Laboratory Overview

Degree:	B.Tech	*Program:*	EE
Year / Semester :	3 / 6	*Academic Year:*	2019
Course Title:	Control system Lab	*Course Code:*	15EEL67
Credit / L-T-P:	2 / 0-1-2	*SEE Duration:*	180 Minutes
Total Contact Hours:	42 Hrs	*SEE Marks:*	80 Marks
CIA Marks:	20	*Assignment*	-
Lab. Plan Author:	Mrs. Shravanthi A	*Sign*	Dt :
Checked By:		*Sign*	Dt :

2. Laboratory Content

Expt.	Title of the Experiments	Lab Hours	Concept	Blooms Level
1	Experiment to draw the speed torque characteristics of (i) AC servo motor (ii) DC servo motor	3	AC and DC servomotors	L3
2	Experiment to draw synchro pair characteristics	3	Synchro transmitter.	L3
3	Experiment to determine the frequency response of a second-order system.	3	second-order system.	L3
4	(a)To design a passive RC lead compensating network for the given specifications, viz., the Maximum phase lead and the frequency at which it occurs and to obtain the frequency Response. (b) To determine experimentally the transfer function of the lead compensating network.	3	RC lead compensating network	L5
5	(a)To design a passive RC lag compensating network for the given specifications., viz., the maximum Phase lag and the frequency at which it occurs, and to obtain the frequency response. (b) To determine experimentally the transfer function of the lag compensating network.	3	RC lag compensating network	L5
6	Experiment to draw the frequency response characteristic of a given lag- lead compensating network ad determination of its transfer function	3	Lag- Lead compensating network	L5
7	(a) To Simulate a typical second order system and determination	3	Second	L5

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	of step response and evaluation of time- domain specifications. (b) Evaluation of the effect of additional poles and zeroes on time response of second order system. (c) Evaluation of the effect of additional poles and zeroes on time response of second order system. (d) Effect of loop gain of a negative feedback system on stability		order system	
8	To simulate a second order system and study the effect of (a) P, (b) PI, (c) PD and (d) PID controller on the step response.	3	Controller	L5
9	(a)To simulate a D. C. position control system and obtain its step response. b) To verify the effect of the input wave form, loop gain system type on steady state errors. c) To perform a trade-off study for lead compensation d) To design a PI controller and study its effect on steady state error.	3	DC position control system	L5
10	a) To examine the relationships between open-loop frequency response and stability, open loop frequency and closed loop transient response. (b) To study the effect of open loop gain on transient response of closed loop system using root locus.	3	Root Locus	L4
11	(a) To study the effect of open loop poles and zeros on root locus contour. (b) To estimate the effect of open loop gain on the transient response of closed loop system by using Root locus. c) Comparative study of Bode, Nyquist and Root locus with respect to Stability.	3	Bode, Nyquist and Root locus	L3

3. Laboratory Material

Books & other material as recommended by university (A, B) and additional resources used by Laboratory teacher (C).

Expt.	Details	Expt. in book	Availability
A	**Text books (Title, Authors, Edition, Publisher, Year.)**	**-**	**-**
1, 2, 3, 4, 5	Anand Kumar , “Control Systems” PHI 2nd Edition, 2014	In Lib	Anand Kumar , “Control Systems” PHI 2nd Edition, 2014
B	**Reference books (Title, Authors, Edition, Publisher, Year.)**	**-**	**-**
1, 2	Farid Golnaraghi, Benjamin C. Kuo , “Automatic Control Systems”, Wiley, 9th Edition, 2010		dept
1, 2	Norman S. Nise, “Control Systems Engineering”, Wiley, 4th Edition, 2004.		In dept
3, 4, 5	Norman S. Nise, “Control Systems, Principles and Design ”, Wiley, 4th Edition, 2012.		
C	**Concept Videos or Simulation for Understanding**	**-**	**-**
C1	https://nptel.ac.in/courses/108107115/13		
C2	https://nptel.ac.in/courses/108105064/30		

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C3	https://nptel.ac.in/courses/112107242/20		
C4	https://www.youtube.com/watch?v=Xgr9AA0RnSo		
C5	https://nptel.ac.in/courses/108103008/20		
C6	https://nptel.ac.in/courses/108106098/35		
C7	https://nptel.ac.in/courses/112107242/20		
C8	:http://nptel.ac.in/courses/108106098/27		
C9	:http://nptel.ac.in/courses/108106098/27		
C10	https://nptel.ac.in/courses/108101037/30		
C11	https://nptel.ac.in/courses/108101037/39 https://nptel.ac.in/courses/108101037/41		
D	**Software Tools for Design**	**-**	**-**
	MATLAB SIMULINK/ SCILAB		
E	**Recent Developments for Research**	**-**	**-**
	We recommend taking MATLAB Onramp: https://www.mathworks.com/learn/tutorials/matlab-onramp.html>		
		?	In lib
F	**Others (Web, Video, Simulation, Notes etc.)**	**-**	**-**

4. Laboratory Prerequisites:

Refer to GL01. If prerequisites are not taught earlier, GAP in curriculum needs to be addressed. Include in Remarks and implement in B.5.

Students must have learnt the following Courses / Topics with described Content . . .

Expt.	Lab. Code	Lab. Name	Topic / Description	Sem	Remarks	Blooms Level
1	15EE61	Control System	Time Domain Analysis Root locus technique Frequency Response analysis Bode plots Nyquist plot Design of Control Systems	6		Understand L2
-						
-						

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5. Content for Placement, Profession, HE and GATE

The content is not included in this course, but required to meet industry & profession requirements and help students for Placement, GATE, Higher Education, Entrepreneurship, etc. Identifying Area / Content requires experts consultation in the area.
Topics included are like, a. Advanced Topics, b. Recent Developments, c. Certificate Courses, d. Course Projects, e. New Software Tools, f. GATE Topics, g. NPTEL Videos, h. Swayam videos etc.

Expt.	Topic / Description	Area	Remarks	Blooms Level
11	Root locus concepts, Bode plot, Nyquist stability	New Software Tools,		L3,L4
-				

B. Laboratory Instructions

1. General Instructions

SNo	Instructions	Remarks
1	Observation book and Lab record are compulsory.	
2	Students should report to the concerned lab as per the time table.	
3	After completion of the program, certification of the concerned staff in-charge in the observation book is necessary.	
4	Student should bring a notebook of 100 pages and should enter the readings /observations into the notebook while performing the experiment.	
5	The record of observations along with the detailed experimental procedure of the experiment in the Immediate last session should be submitted and certified staff member in-charge.	
6	Should attempt all problems / assignments given in the list session wise.	
7	It is responsibility to create a separate directory to store all the programs, so that nobody else can read or copy.	
8	When the experiment is completed, should disconnect the setup made by them, and should return all the components/instruments taken for the purpose.	
9	Any damage of the equipment will be viewed seriously either by putting penalty or by dismissing the total group of students from the lab for the semester/year	
10	Completed lab assignments should be submitted in the form of a Lab Record in which you have to write the algorithm, program code along with comments and output for various inputs given	

2. Laboratory Specific Instructions

SNo	Specific Instructions	Remarks
1	Enter the command window of the MATLAB.	
2	Create a new M – file by selecting File - New – M – File	
3	Type and save the program in the editor window.	
4	Execute the program by pressing Tools – Run.	
5	View the results.	

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C. OBE PARAMETERS

1. Laboratory Outcomes

Expt.	Lab Code #	COs / Experiment Outcome	Teach. Hours	Concept	Instr Method	Assessment Method	Blooms' Level
-	-	**At the end of the experiment, the student should be able to . . .**	-	-	-	-	-
1	15EEL67.1	Determine the performance characteristics of ac and dc servomotors	6	AC and DC Servomotors	Black Board + Execution	Slip Test + Viva	L3
2	15EEL67.2	Determine the performance characteristics of synchro-transmitter receiver pair	03	Synchro transmitter.	Black Board + Execution	Slip Test + Viva	L3
3	15EEL67.3	Determine the frequency response of a second-order system	03	second-order system.	Black Board + Execution	Slip Test + Viva	L3
4	15EEL67.4	Design and analyze RC lead compensating network for given specifications	03	RC lead compensating network	Black Board + Execution	Slip Test + Viva	L5
5	15EEL67.5	Design and analyze RC lag compensating network for given specifications	03	RC lag compensating network	Black Board + Execution	Slip Test + Viva	L5
6	15EEL67.6	Design and analyze Lag- Lead compensating network for given specifications	03	Lag- Lead compensating network	Black Board + Execution	Slip Test + Viva	L5
7	15EEL67.7	Use MATLAB software package in assessing the time domain response of a given second order system.	03	Second order system	Black Board + Execution	Slip Test + Viva	L5
8	15EEL67.8	To study the effect of P, PI, PD and PID controller on the step response of a feedback control system (using control engineering trainer/process control simulator) and Verifying the same by simulation.	03	Controller	Black Board + Execution	Slip Test + Viva	L5
9	15EEL67.9	Simulate a DC position control system using MATLAB and obtain its step response and to design PI controller and study its effect on steady state error.	03	DC position control system	Black Board + Execution	Slip Test + Viva	L5
10	15EEL67.10	To analyse the relationship between open-loop frequency response and stability, open-loop frequency and closed loop transient response and to study the effect of open loop gain using root locus	06	Root Locus	Black Board + Execution	Slip Test + Viva	L4
11	*15EEL67.11*	Write a script files to plot root locus, bode plot, Nyquist plots to study the stability of the system using a software	06	Bode, Nyquist and Root locus	Black Board + Execution	Slip Test + Viva	L3
-		**Total**	**60**	-	-	-	-

Note: Identify a max of 2 Concepts per unit. Write 1 CO per concept.

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2. Laboratory Applications

Expt.	Application Area	CO	Level
1	AC servomotor are widely used in remote positioning devices, process control systems, self balancing recorders, computers, tracking and recording systems, robotics, machine tools etc.. DC servomotor are widely used in air craft control systems, electrochemical actuators, robotics, machine tools etc.	CO1	L3
2	In a control system, a synchro will provide a voltage for conversion to torque through an amplifier and a servomotor. Control type synchros are used in applications that require large torques or high accuracy such as follow-up links and error detectors in servo, automatic control systems (such as an autopilot system).	CO2	L3
3	Stability analysis and design	CO3	L3
4	Lead and lag compensators are used quite extensively in control. A lead compensator can increase the stability or speed of reponse of a system; a lag compensator can reduce (but not eliminate) the steady-state error	CO4	L5
5	Lead and lag compensators are used quite extensively in control. A lead compensator can increase the stability or speed of reponse of a system; a lag compensator can reduce (but not eliminate) the steady-state error	CO5	L5
6	Lead–lag compensators influence disciplines as varied as robotics, satellite control, automobile diagnostics, and laser frequency stabilization. They are an important building block in analog control systems, and can also be used in digital control.	CO6	L5
7	Step response and evaluation of time- domain specifications.	CO7	L5
8	Controllers improve steady state accuracy by decreasing the steady state errors. As the steady state accuracy improves, the stability also improves. They also help in reducing the offsets produced in the system. Maximum overshoot of the system can be controlled using these controllers. They also help in reducing the noise signals produced in the system. Slow response of the over damped system can be made faster with the help of these controllers.	CO8	L5
9	D.C. position control system it is required to keep the position of the load constant. Such a system where output position is kept constant is called as position control system. The output position is sensed and feedback to the potentiometer used as an error detector.	CO9	L5
10	Root Locus is a technique used as a stability criterion in the field of classical control theory developed by Walter R. Evans which can determine stability of the system. The root locus plots the poles of the closed loop transfer function in the complex s-plane as a function of a gain parameter.	CO10	L4
11	Root Locus is a technique used as a stability criterion in the field of classical control theory developed by Walter R. Evans which can determine stability of the system. The root locus plots the poles of the closed loop transfer function in the complex s-plane as a function of a gain parameter. A Bode Plot is a useful tool that shows the gain and phase response of a given LTI system for different frequencies. Bode Plots are generally used with the Fourier Transform of a given system. An example of a Bode magnitude and phase plot set. A Nyquist plot is a parametric plot of a frequency response used in automatic control and signal processing. The most common use of Nyquist plots is for assessing the stability of a system with feedback. In Cartesian coordinates, the real part of the transfer function is plotted on the X axis.	CO11	L3

Note: Write 1 or 2 applications per CO.

3. Mapping And Justification

CO – PO Mapping with mapping Level along with justification for each CO-PO pair.
To attain competency required (as defined in POs) in a specified area and the knowledge & ability required to accomplish it.

Expt	Mapping	Mapping	Justification for each CO-PO pair	Lev

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.			Level		el
-	CO	PO	-	**'Area': 'Competency' and 'Knowledge' for specified 'Accomplishment'**	-
1	CO1	PO1	2.77	Knowledge on servomotors.	L2
1	CO1	PO2	2.77	Analyzing the performance characteristics of ac and dc servomotors.	L4
2	CO2	PO1	2.77	Knowledge on synchro motor	L2
2	CO2	PO2	2.77	To analyze the performance characteristics of synchro-transmitter receiver pair.	L4
3	CO3	PO1	2.77	Knowledge on frequency response analysis	L2
3	CO3	PO2	2.77	To analyse the frequency domain reposes of a given second order system using discrete components.	L4
4	CO4	PO1	2.77	Knowledge on design of control systems	L2
4	CO4	PO2	2.77	To analyze Lead compensators for given specifications.	L4
4	CO4	PO3	2.5	Design and analyze Lead compensators for given specifications.	L6
4	CO4	PO9	2.5	Projects or internship on Lead compensator.	L3
5	CO5	PO1	2.77	Knowledge on design of control systems	L2
5	CO5	PO2	2.77	To analyze Lag compensators for given specifications.	L4
5	CO5	PO3	2.5	Design and analyze Lag compensators for given specifications.	L6
5	CO5	PO9	2.5	Projects or internship on Lag compensator.	L3
6	CO6	PO1	2.77	Knowledge on design of control systems	L2
6	CO6	PO2	2.77	To analyze Lag lead compensators for given specifications.	L4
6	CO6	PO3	2.5	Design and analyze Lag lead compensators for given specifications.	L6
6	CO6	PO9	2.5	Projects or internship on Lag Lead compensator.	L3
7	CO7	PO1	2.77	Knowledge on time domain analysis	L2
7	CO7	PO2	2.77	To analyse the time domain reposes of a given second order system using software package or discrete components.	L4
7	CO7	PO5	2.8	To determine frequency domain reposes of a given second order system using software package.	L3
8	CO8	PO1	2.77	Knowledge on design of control systems	L2
8	CO8	PO2	2.77	To analyze the effect of P, PI, PD and PID controller on the step response of a feedback control system (using control engineering trainer/process control simulator) and Verifying the same by simulation.	L5
8	CO8	PO5	2.8	To simulate a second order system and study the effect of (a) P, (b) PI, (c) PD and (d) PID controller on the step response using software package.	L3
8	CO8	PO9	2.5	Projects or internship on Controllers.	L3
9	CO9	PO1	2.77	Knowledge on DC Position control system.	L2
9	CO9	PO2	2.77	Analyze DC position control system using MATLAB and obtain its step response.	L5
9	CO9	PO3	2.5	Design PI controller and study its effect on steady state error.	L6
9	CO9	PO5	2.8	Simulate DC position control system using MATLAB and obtain its step response.	L3
9	CO9	PO9	2.5	Projects or internship on PI Controllers.	L3
10	CO10	PO1	2.77	Knowledge on Root locus	L2
10	CO10	PO2	2.77	To analyse the relationship between open-loop frequency response and stability, open-loop frequency and closed loop transient response and to study the effect of open loop gain using root locus	L5
10	CO10	PO5	2.8	To study the effect of open loop gain on transient response of closed loop system using root locus with the help of software package.	L3
11	CO11	PO1	2.77	Knowledge on Root locus, Bode Plot and Nyquist Plots	L2
11	CO11	PO2	2.77	To Analyze the stability of the system using root locus, bode plot, Nyquist plots.	L4
11	CO11	PO5	2.8	To Analyze the stability of the system using software package by writing a script files to plot root locus, bode plot, Nyquist plots.	L3

4. Articulation Matrix

CO – PO Mapping with mapping level for each CO-PO pair, with course average attainment.

-	-	Experiment Outcomes	Program Outcomes															-
Expt.	CO.#	**At the end of the experiment**	PO	PO	PO	PO	PO	PO	PO	PO	PO	PO	PO	PO	PS	PS	PS	Lev

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		student should be able to . . .	1	2	3	4	5	6	7	8	9	10	11	12	O1	O2	O3	el
1	15EEL67.1	Determine the performance characteristics of ac and dc servomotors	2.77	2.77														L2
2	15EEL67.2	Determine the performance characteristics of synchro-transmitter receiver pair	2.77	2.77														L2
3	15EEL67.3	Determine the frequency response of a second-order system	2.77	2.77														L2
4	15EEL67.4	Design and analyze RC lead compensating network for given specifications	2.77	2.77	2.5						2.5							L3
5	15EEL67.5	Design and analyze RC lag compensating network for given specifications	2.77	2.77	2.5						2.5							L2
6	15EEL67.6	Design and analyze Lag- Lead compensating network for given specifications	2.77	2.77	2.5						2.5							L2
7	15EEL67.7	Use MATLAB software package in assessing the time domain response of a given second order system.	2.77	2.77			2.8											L3
8	15EEL67.8	To study the effect of P, PI, PD and PID controller on the step response of a feedback control system (using control engineering trainer/process control simulator) and Verifying the same by simulation.	2.77	2.77			2.8				2.5							L2
9	15EEL67.9	Simulate a DC position control system using MATLAB and obtain its step response and to design PI controller and study its effect on steady state error.	2.77	2.77	2.5		2.8				2.5							L2
10	15EEL67.10	To analyse the relationship between open-loop frequency response and stability, open-loop frequency and closed loop transient response and to study the effect of open loop gain using root locus	2.77	2.77			2.8											L3
11	15EEL67.11	Write a script files to plot root locus, bode plot, Nyquist plots to study the stability of the system using a software	2.77	2.77			2.8											
	15EEL67	**Average attainment (1, 2, or 3)**																
	PO, PSO	*1.Engineering Knowledge; 2.Problem Analysis; 3.Design / Development of Solutions; 4.Conduct Investigations of Complex Problems; 5.Modern Tool Usage; 6.The Engineer and Society; 7.Environment and Sustainability; 8.Ethics; 9.Individual and Teamwork; 10.Communication; 11.Project Management and Finance; 12.Life-long Learning; S1.Software Engineering; S2.Data Base Management; S3.Web Design*																

5. Curricular Gap and Experiments

Topics & contents not covered (from A.4), but essential for the course to address POs and PSOs.

Expt	Gap Topic	Actions Planned	Schedule Planned	Resources Person	PO Mapping

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1					
2					
3					
4					
5					

Note: Write Gap topics from A.4 and add others also.

6. Experiments Beyond Syllabus

Topics & contents required (from A.5) not addressed, but help students for Placement, GATE, Higher Education, Entrepreneurship, etc.

Expt	Gap Topic	Actions Planned	Schedule Planned	Resources Person	PO Mapping
1					
2					
3					

D. COURSE ASSESSMENT

1. Laboratory Coverage

Assessment of learning outcomes for Internal and end semester evaluation. Distinct assignment for each student. 1 Assignment per chapter per student. 1 seminar per test per student.

Unit	Title	Teaching Hours	No. of question in Exam							CO	Levels
			CIA-1	CIA-2	CIA-3	Asg-1	Asg-2	Asg-3	SEE		
1	Experiment to draw the speed torque characteristics of (i) AC servo motor (ii) DC servo motor	03	1	-	-	-	-	-	1	CO1	L5
2	Experiment to draw synchro pair characteristics	03	1	-	-	-	-	-	1	CO2	L5
3	Experiment to determine the frequency response of a second-order system.	03	1	-	-	-	-	-	1	CO3	L5
4	(a)To design a passive RC lead compensating network for the given specifications, viz., the Maximum phase lead and the frequency at which it occurs and to obtain the frequency Response. (b) To determine experimentally the transfer function of the lead compensating network.	03	1	-	-	-	-	-	1	CO4	L5
5	(a)To design a passive RC lag compensating network for the given specifications., viz., the maximum Phase lag and the frequency at which it occurs, and to obtain the frequency response. (b) To determine experimentally the transfer function of the lag compensating network.	03	-	1	-	-	-	-	1	CO5	L5
6	Experiment to draw the frequency response characteristic of a given lag- lead compensating network	03	-	1	-	-	-	-	1	CO6	L5

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	ad determination of its transfer function										
7	(a) To Simulate a typical second order system and determination of step response and evaluation of time- domain specifications. (b) Evaluation of the effect of additional poles and zeroes on time response of second order system. (c) Evaluation of the effect of additional poles and zeroes on time response of second order system. (d) Effect of loop gain of a negative feedback system on stability	03	-	1	-	-	-	-	1	CO7	L5
8	To simulate a second order system and study the effect of (a) P, (b) PI, (c) PD and (d) PID controller on the step response.	03	-	-	1	-	-	-	1	CO8	L5
9	(a)To simulate a D. C. position control system and obtain its step response. b) To verify the effect of the input wave form, loop gain system type on steady state errors. c) To perform a trade-off study for lead compensation d) To design a PI controller and study its effect on steady state error.	03	-	-	1	-	-	-	1	CO9	L5
10	a) To examine the relationships between open-loop frequency response and stability, open loop frequency and closed loop transient response. (b) To study the effect of open loop gain on transient response of closed loop system using root locus.	03	-	-	1	-	-	-	1	CO10	L5
11	(a) To study the effect of open loop poles and zeros on root locus contour. (b) To estimate the effect of open loop gain on the transient response of closed loop system by using Root locus. c) Comparative study of Bode,										

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	Nyquist and Root locus with respect to Stability.										
-	**Total**		**4**	**3**	**3**	**5**	**5**	**5**	**20**	**-**	**-**

2. Continuous Internal Assessment (CIA)

Assessment of learning outcomes for Internal exams. Blooms Level in last column shall match with A.2.

Evaluation	Weightage in Marks	CO	Levels
CIA Exam – 1	30	CO1, CO2, CO3, CO4	L1, L2, L3,L4
CIA Exam – 2	30	CO5, CO6, CO7,	L5, L6, L7
CIA Exam – 3	30	CO8, CO9,CO10	L8, L9, L10
Assignment - 1	05	CO1, CO2, CO3, CO4	L1, L2, L3,L4
Assignment - 2	05	CO5, CO6, CO7,	L5, L6, L7
Assignment - 3	05	CO8, CO9,CO10	L8, L9, L10
Seminar - 1			
Seminar - 2			
Seminar - 3			
Other Activities – define – Slip test			
Final CIA Marks	**40**	**-**	**-**

-

SNo	Description	Marks
1	Observation and Weekly Laboratory Activities	05 Marks
2	Record Writing	10 Marks for each Expt
3	Internal Exam Assessment	25 Marks
4	Internal Assessment	15 Marks
5	SEE	80 Marks
-	**Total**	**100 Marks**

E. EXPERIMENTS

Experiment 01 : (i)TORQUE- SPEED CHARACTERISTICS OF AC SERVO MOTOR
(ii) TORQUE- SPEED CHARACTERISTICS OF DC SERVO MOTOR

-	Experiment No.:	1 (i)	Marks		Date Planned		Date Conducted	
1	Title	Experiment to draw the speed torque characteristics of (i) AC servo motor						
2	Course Outcomes	Determine the performance characteristics of ac servomotor.						
3	Aim	Obtain the torque - speed characteristics of ac servo motor with the following control voltages:						

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		1. Rated value (100%) 2. 70% of the rated voltage 3. 50% of the rated voltage
4	Material / Equipment Required	AC Servomotor unit, voltmeter (MI)0-250V, Voltmeter (MC) 0-15V.
5	Theory, Formula, Principle, Concept	Servo motors are called control motors and have high torque capabilities. Unlike large industrial motors they are not used for continuous energy conversion but only used for precise speed and precise position control at high torque. Their power rating varies from a fraction of a watt up to a few 100w. Due to their low inertia they have high speed of response. These motors are designed to have linear torque/speed characteristics with negative slope. The negative slope serves the purpose of providing viscous damping for the servo motor drive An AC servo motor is essentially a two phase induction motor consisting of two stator windings separated by 90 deg. Electrical in space and a squirrel cage rotor Construction wise it is similar to an induction motor except for a special design features. In servomechanism an IM is required to produce rapid acceleration from standstill. Therefore the rotor diameter is kept as small as possible in order to reduce inertia and get good acceleration. Balanced voltages applied to the two stator winding which differ in time phase by 90 deg. One phase is known as reference phase which is excited by a constant voltage and the other is known as control phase which is energized by a variable voltage and polarity **To find torque developed by the ac servomotor**: Electrical power developed Pg = EgIa watts Mechanical power developed = $\omega T = 2\pi nT$ watts where n in rps = N/60 According to Newton's law of conservation of energy both the powers are equal and hence $\omega T = E_g I_a$ or $T = P_g/\omega = P_g / (2\pi n) = P_g / 2\pi(N/60)$ $T = 60P_g/(2\pi N)$ Nm
6	Procedure, Program, Activity, Algorithm, Pseudo Code	1. Connections are made as per the circuit diagram shown in the figure. 2. Connect a voltmeter across the control winding of ac servomotor to measure control voltage. 3. With the load switch in off position and auto transformer knob at minimum position, the main supply is switched on and then servomotor switch is made on. 4. Vary the auto transformer knob from minimum position and the motor starts running. Vary the auto-transformer knob until the voltmeter connected across control winding reads rated value.(200V). 5. Note down the corresponding values of induced Emf Eg, no-load current and no-load speed. 6. Now load is switched on and the load is applied gradually in suitable steps. For each load the readings of induced Emf Eg, load current and speed are noted down. These readings give the torque-speed characteristics of ac servomotor at rated voltage. 7. To obtain the torque - speed characteristics for 70% of the rated voltage (140V), adjust the auto-transformer till the voltmeter across the control windings reads 140Vand the same procedure is repeated. 8. To obtain the torque - speed characteristics for 50% of the rated voltage (100V), adjust the auto-transformer till the voltmeter across the control windings reads 100Vand the same procedure is repeated.
7	Block, Circuit, Model	

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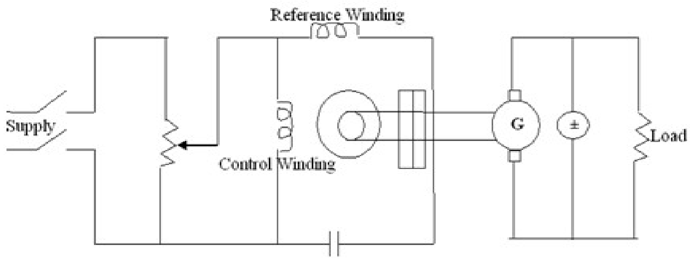
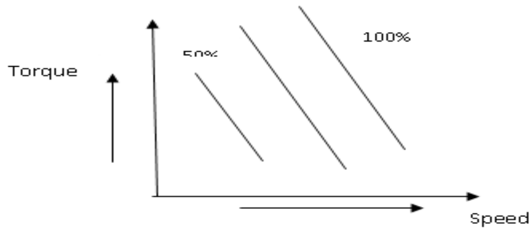
Diagram, Reaction Equation, Expected Graph





8 Observation Table, Look-up Table, Output

- For 100%(or rated value) of the control voltage=200volts

Speed N(rpm)	Load current (Amps)	Induced EMF Eg(Volts)	Power developed P=Eg x I (Watts)	Torque

- For 70% of the control voltage = 140V

Speed N(rpm)	Load current (Amps)	Induced EMF Eg(Volts)	Power developed P=Eg x I (Watts)	Torque

- For 50% of the control voltage=100volts

Speed N(rpm)	Load current (Amps)	Induced EMF Eg(Volts)	Power developed P=Eg x I (Watts)	Torque

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9	Sample Calculations					
10	Graphs, Outputs					
11	Results & Analysis	1. Families of torque /speed characteristics of the AC servo motor are plotted for 100%, 70% and 50% of the control voltage. 2. All these torque /speed curves have negative slope. On the low speed region the curves are nearly linear and equidistant, that is, the torque varies linearly with the speed and control voltages. 3. The AC servomotors have good accelerating char due to high torque / inertia ratio				
12	Application Areas	AC servomotor are widely used in remote positioning devices, process control systems, self balancing recorders, computers, tracking and recording systems, robotics, machine tools etc..				
13	Remarks					
14	Faculty Signature with Date					

-	Experiment No.:	1 (ii)	Marks		Date Planned		Date Conducted	
1	Title	Experiment to draw the speed torque characteristics of (i) DC servo motor						
2	Course Outcome	Determine the performance characteristics of dc servomotor.						
3	Aim	Obtain the torque speed characteristics of dc servo motor with the following control voltages: Rated value (100%) 60% of the rated voltage 40% of the rated voltage						
4	Material / Equipment Required	DC Servomotor cum Brake Drum load arrangement unit, Voltmeter 0-50V						
5	Theory, Formula, Principle, Concept	The mechanism in which the control variable is adjusted by the error served by comparing output and input is called servomechanism. Any quantity example voltage, speed, temperature, position, torque, etc. be controlled by providing appropriate feedback. The motor which respond to the error signal abruptly and actuate the load quickly are called servomotors. These are specifically designed and built primarily for use in feedback control systems as output actuators. The power ratings can vary from a fraction of a watt upto a few hundred watts. They have high speed response which requires low rotor inertia. These motors are therefore smaller in diameter and longer in length. DC servomotors are used in high power applications. Some DC motors with relatively small power rating are used in instruments and computer related instruments. Other applications are CNC machines, robot systems, radars, machine tools, etc. most important among the characteristics of the DC servomotor is the maximum acceleration. The operation of this motor is same as normal DC motor. The DC servomotors generally used are of permanent magnet DC motors and their speed is controlled by armature voltage. These motors have high torque/ inertia ratio and high operating efficiency and no field losses. The armature						

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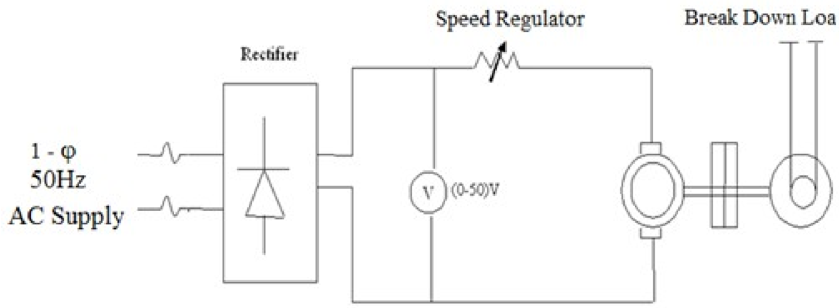
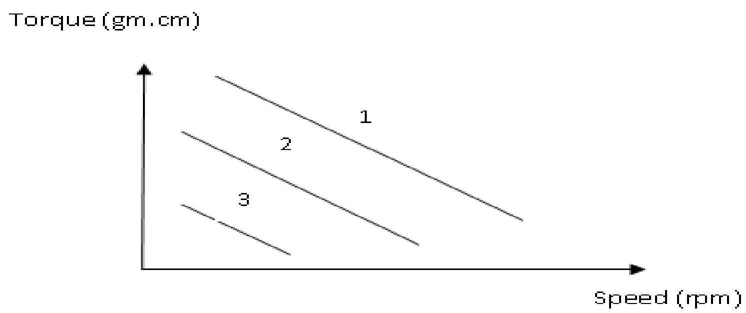
		controlled motor back emf contributes additional damping in addition to the load friction. The speed is almost directly proportional to the armature voltage at a given load torque. Torque = K*w*R Where K=1= Constant R=Radius of the pully in cms W=Total weight gms.
6	Procedure, Program, Activity, Algorithm, Pseudo Code	1. Connections are made as per the circuit diagram shown in the figure. 2. Connect an voltmeter across the motor armature terminals (Marked 24 V DC on the motor) to measure the control voltage. 3. With no-load on the motor and the speed regulator at minimum position, the main supply is switched on and then servo motor switch is put on. 4. The speed regulator knob is gradually varied from minimum position to the maximum position until the voltmeter reads the rated control voltage (24 V) and the corresponding no-load current and no-load speed is noted down. 5. Now the load is applied on the motor by rotating the wheel of the brake drum load arrangement and the current speed, spring balance readings w1 and w2 are noted down for every 25gms or 50 gms of load. 6. Release the load gradually. 7. These readings give the torque -speed characteristics of dc servo motor at rated control voltage. 8. To obtain the torque - speed characteristics for 60% of the control voltage , adjust the speed regulator knob till the voltmeter reads required value and the same procedure is repeated. 9. To obtain the torque - speed characteristics for 40% of the control voltage , adjust the speed regulator knob till the voltmeter reads required value and the same procedure is repeated.
7	Block, Circuit, Model Diagram, Reaction Equation, Expected Graph	 
8	Observation Table,	• For voltage=……………….V(100%)

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Look-up Table, Output

Speed N (rpm)	Control Voltage 100%	Load Current(A)	Load W_1 (gms)	Load W_2 (gms)	W_1-W_2 (Gms)	Torque (gm-cm) T=(W1-W2)R

- For voltage=......................V(60%)

Speed N (rpm)	Control Voltage 100%	Load Current(A)	Load W_1 (gms)	Load W_2 (gms)	W_1-W_2 (Gms)	Torque (gm-cm) T=(W1-W2)R

- For voltage=......................V(40%)

Speed N (rpm)	Control Voltage 100%	Load Current(A)	Load W_1 (gms)	Load W_2 (gms)	W_1-W_2 (Gms)	Torque (gm-cm) T=(W1-W2)R

9	Sample Calculations	
10	Graphs, Outputs	
11	Results & Analysis	1. A family of torque speed characteristics of pmdc servomotor are plotted for 100%, 60% and 40% of control voltage. 2. The speed of a dc servomotor is nearly directly proportional to the armature control voltage.

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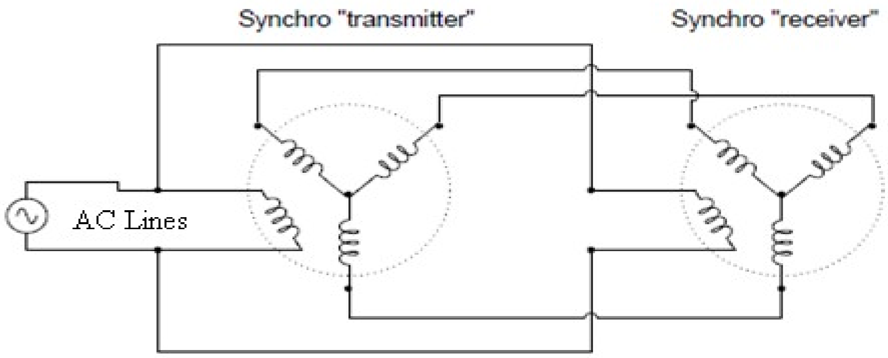
		3. All these torque speed curves have negative slopes. In low speed region the curves are nearly linear and equidistant, that is the torque varies linearly with speed and control voltages. A servomotor normally operates at low speed in control applications. Eg: Position control system 4. PMDC servomotor have much higher torque/inertia ratio giving good accelerating characteristics and higher operating efficiency as pmdc servomotors have no losses. A much lower inertia is achieved by placing the winding on a non magnetic cylinder.
12	Application Areas	DC servomotor are widely used in air craft control systems, electrochemical actuators, robotics, machine tools etc.
13	Remarks	
14	Faculty Signature with Date	

Experiment 02 : Study of Synchro Transmitter

-	Experiment No.:	2	Marks		Date Planned		Date Conducted	
1	Title	Experiment to draw synchro pair characteristics						
2	Course Outcomes	Determine the performance characteristics of synchro-transmitter receiver pair						
3	Aim	To study about synchro transmitter – receiver pair.						
4	Material / Equipment Required	Synchro transmitter – receiver pair kit, Connecting wires						
5	Theory, Formula, Principle, Concept	A  Synchro Motor is a Elecrical motor consition out of a single-phase Inner/Rotor windings, and a Three-phase Outer/Stator windings. The Outer/Stator windings are connected Electricly in a Star formation. ... ie: The inner ends of each the three windings are connected to one another. And the outer ends will then be connected to another Synchro Motors outer ends. The Inner/Rotor windings are connected to a single-phase AC power supply. The Rotor Windings in turn transfer energy over to the Outer/Stator windings. The Stator Windings are 120 degrees apart. And therefore depending on the Rotation of the Inner/Rotor Windings the Outer/Stator Winding get a different magnitude of magnetic flux, transferring a different amount of current flow to each of the three Outer/Sator windings. That bring us to the use of a Synchro Motor: ... A Synchro Motor works in pairs of 2 or 3, and are used to transfer rotational orientation from one Synchro motor to another. Depending on how the Synchro Motors are connected to one another you can mirror the rotation from the first motor to the second. For standard Synchronigation you would connect The 3 Outer/Stator windings as such (1-1) (2-2) & (3-3). To mirror the Rotation you could connect (1-2) (2-1) & (3-3). There can be 3 Synchro motors. The Third is wired differently inside. It has 3 Inner/Rotor windings & 3 Outer/Stator windings.						

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		The Rotor & Stator winding are connected in a star formation. The third Synchromotor bring about a difference in rotation. You could add or subtract rotational orientations. A = Synchro Motor 1. B = Synchro Motor 2 (with 3 Stator & 3 Rotor windings). C = Synchro Motor 3. A+B=C or A-B=C. Synchro motors are used in ships, for opening & closing valves from the bridge to for instance the Engine room. A more advanced system of the Synchro technology integrates with a Servo Motor that in turn can control the rudder of the ship. Other uses are in Analog computers & Electronic Weapon Guidance Systems
6	Procedure, Program, Activity, Algorithm, Pseudo Code	1. Connect the mains supply to the synchro Transmitter – Receiver system with the help of the given mains cord. 2. Connect the stator terminals of transmitter S_1, S_2 and S_3 with Stator terminals of receiver $S1'$, $S2'$ and $S3'$ with the help of patch cords respectively. 3. Switch on the mains supply of the kit and also the rotor's supply of both transmitter and receiver. 4. Now at zero angular position of rotor of transmitter, note down that of receiver and tabulate them. 5. Vary the angular positions of rotor of transmitter in steps by 30° and note down the corresponding angular positions of rotor of receiver. 6. Plot a graph between angular positions of rotor of transmitter and angular positions of rotor of receiver. 7. Switch off the mains supply of the kit and also the rotor's supply of both transmitter and receiver.
7	Block, Circuit, Model Diagram, Reaction Equation, Expected Graph	
8	Observation Table, Look-up Table, Output	(see table below)

Sl. No.	Angular positions of transmitter	Angular positions of receiver
1	0	
2	30	
3	60	
4	90	
5	120	
6	150	
7	180	
8	210	
9	240	
10	270	
11	300	
12	330	

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		13	360 or 0	
9	Sample Calculations			
10	Graphs, Outputs			
11	Results & Analysis			
12	Application Areas	Thus the characteristics of synchro transmitter – receiver pair were studied.		
13	Remarks			
14	Faculty Signature with Date			

Experiment 03: FREQUENCY RESPONSE OF A SECOND-ORDER SYSTEM

-	**Experiment No.:**	3	**Marks**		**Date Planned**		**Date Conducted**	
1	Title	Experiment to determine frequency response of a second order system						
2	Course Outcomes	Determine the frequency response of a second-order system						
3	Aim	Conduct an experiment to determine the frequency response of a second-order system and evaluation of frequency domain specifications						
4	Material / Equipment Required	Generator-1No., Probe wire-1No., DRB-1No., DIB-1No., DCB-1No., Multimeter-1No.						
5	Theory, Formula, Principle, Concept	The frequency response of a second-order system is the graph plotted on a semilog sheet taking frequency in the x-axis and magnitude in the y-axis. The frequency domain specifications are resonant peak Mr, the resonant frequency ωr at which it occurs and band width. For satisfactory operation, Mr value should be within 1 to 1.4 or 0 to 3dB and ξ value between 0.4 and 0.707. When damping ratio ξ = 0.707, there is no Mr in the output. The frequency domain methods are (1) Bode plot (2)Polar plot (Root locus) (3) Nyquist plot and (4) Magnitude-phase angle plot. Frequency response methods were used earlier than other methods for stability analysis and design, as compared to root locus methods and digital computer simulation. Advantages of frequency domain approach are (1)without the knowledge of the TF, the freq. response of a stable open loop system can be obtained experimentally (2) We can use these methods for finding absolute and relative stability of the system. The disadvantage of these systems are (1) method applicable to only linear systems (2) method is time consuming (3) applicable to the systems having time constants a few minutes. A series RLC circuit can be used to study the time response of a second order system. The voltage across the capacitor to a step input is analogous to step response of any second order system. The TF of a series RLC circuit with voltage across capacitor as output is given by $V_0(s)/V_i(s) = [1/LC] / [s2+(R/L)s+1/LC]$ It is similar to the standard form of CLTF of a second order system $C(s)/R(s) = \omega_n^2 / (s^2 + 2\xi\omega_n + \omega_n^2)$ **Specimen calculation for one of the reading**: ω in rad/sec = 2πf = Gain $A_v = V_o / V_i$ = Gain in dB = 20 log (Av) = **Theoretical calculations** 1. Natural frequency (r/s) $\omega_n = 1 / \sqrt{(LC)}$							

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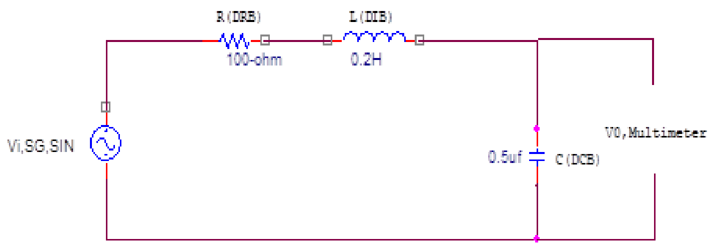
		2. Damping ratio $\xi = R\, \omega n / 2$ 3. Damping frequency (r/s) $\omega_d = \omega_n \sqrt{(1 - \xi^2)}$ 4. Resonant peak (dB) $M_r = 1/ [2\xi \sqrt{(1 - \xi^2)}]$ 5. Resonant frequency(r/s) $\omega_r = \omega_n \sqrt{(1 - 2\xi^2)}$ 6. Band width $W_d = \omega_n \sqrt{[1 - 2\xi 2 + \sqrt{(2-4\xi^2+4\xi^4)}]}$
6	Procedure, Program, Activity, Algorithm, Pseudo Code	1. Rig up the circuit as per circuit diagram 2. In the signal generator, keep power switch in off position, all the knobs in zero position and pressing switches in out position. Similarly in decade boxes, keep all the knobs in zero position. 3. In decade boxes, set the values of resistance, inductance and capacitance to the values given in the circuit diagram. 4. Switch ON signal generator, keep AMPLITUDE knob in maximum position and select SIN wave. Note input rms voltage Vi using a multimeter. Then connect the multimeter across output to measure output rms voltage Vo. 5. In signal generator, select the frequency from lower range to higher range and vary in steps. Note down the corresponding readings of frequency and Vo at each step. During record of readings, note maximum Vo and the frequency at which maximum phase angle occurs. Take few readings after second corner frequency and stop. Switch off the power switch of signal generator and switch off the supply to the circuit. 6. Calculate ωn, ξ, ωd, Mr, ωr, Av and gain in dB. Plot the gain plot on a semi-log sheet. Mark Mp,ωr, corner frequencies, band width Wb and verify with simulated values and theoretical values.
7	Block, Circuit, Model Diagram, Reaction Equation, Expected Graph	
8	Observation Table, Look-up Table, Output	Vi = _________

SL No	F(Hz)	ω (rad)	V_o(volts)	$A_v=V_i/V_o$	

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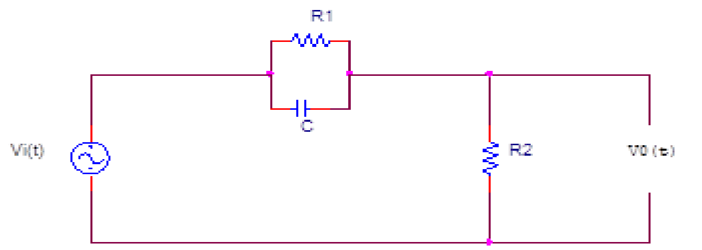
9	Sample Calculation						
10	Graphs, Outputs						
11	Results & Analysis						
12	Application Areas						
13	Remarks						
14	Faculty Signature with Date						

Experiment 04: RC lead compensating network

-	Experiment No.:	4	Marks		Date Planned		Date Conducted	

1	Title	1. a) To design a passive RC lead compensating network for the given specifications, viz., the Maximum phase lead and the frequency at which it occurs and to obtain its frequency Response. b) To determine experimentally the transfer function of the lead compensating network.
2	Course Outcomes	Design and analyze RC lead compensating network for given specifications
3	Aim	1. a) To design a passive RC lead compensating network for the given specifications, viz., the Maximum phase lead and the frequency at which it occurs and to obtain its frequency Response. b) To determine experimentally the transfer function of the lead compensating network.
4	Material / Equipment Required	Lag- lead unit, CRO, voltmeter 0-30V (MI), connecting wires.
5	Theory, Formula, Principle, Concept	If a sinusoidal input is applied to the input of a network, then steady state output has a phase lead. This type of network is called lead compensator network. This network has a zero at s=1/T and a pole at s=1/(αT). Since zero is closer to the origin than pole, this compensator speeds up the transient response and increases the margin of stability of a system. It also helps to increase the system error constant to a limited extent. These compensators are used when fast dynamic response is required. The high pass filter is often referred to as a phase lead controller, since positive phase is introduced to the system over some frequency range. **Circuit diagram for deriving TF**:



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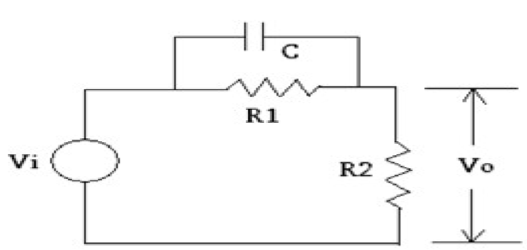
		Design: **Derivation of transfer function of the circuit:** **After taking LT of the above circuit, we get** Vi(s) = (Z1 + Z2) I(s) Where Z1 = R1//C and Z2 = R2 V0(s) = Z2 I(s) TF = V0(s) / Vi(s) = Z2 / (Z1 + Z2) After simplification we get the TF in the form of TF = (s + 1/T) / (s+ 1/αT) where α < 1 Where, Time constant T=R1C secs and α = R2 / (R1 + R2) **Design equations:** **1.** α = (1 – SinΦm) / (1 +SinΦm) (1) Let it be given that Φm = $\sin^{-1}$(1- α/1+α) After substituting in equation (1) and simplifying we get α = 0.0909 Also we have 2. α = R2 / (R1 + R2) (2) Let us select R1 = 10kΩ and substitute in equation (2) R2 = 1kΩ C = 0.01 μF 3. Time constant = T = R_1C 4. Frequency at which maximum phase lead occurs ωm = 1 / (√α) T rad / sec Fm= ωm/2∏ 5. Corner frequency-1 ωc1 = 1 / T rad / sec 6. Corner frequency-2 ωc2 = 1/ (αT) rad / sec Now TF = (s + 1/T) / (s+ 1/αT) =>> TF = (s + 10000) / (s+ 110000)
6	Procedure, Program, Activity, Algorithm, Pseudo Code	1. A passive RC lead compensating network is designed for the given specifications. Connections are made as per the circuit diagram. 2. The output voltage of sine generator is set to 10 V (peak to peak) and is supplied as input to the RC lead compensator. 3. A CRO is connected at the output of the lead compensator. 4. The input frequency of the circuit is varied in steps and the corresponding output voltage is tabulated from CRO in every steps. 5. In addition to this, the phase angle is calculated in every step using Lissajous figures in CRO. 6. The voltage gain is calculated using the formula as given in the table. 7. The plots of gain in dB Vs frequency and phase angle Vs frequency are plotted in semi log sheet
7	Block, Circuit, Model Diagram, Reaction Equation, Expected Graph	

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		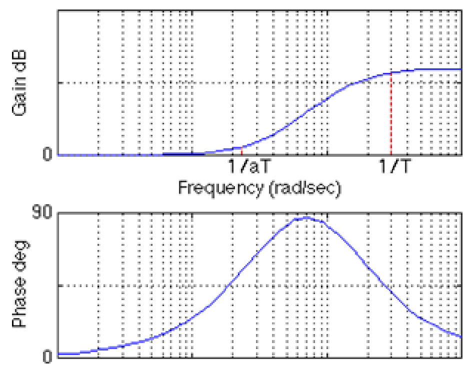
8	Observation Table, Look-up Table, Output	**Input voltage V_i = ________________ volts (Peak-Peak)**

S. No.	**Frequency (Hz)**	**Output Voltage V_o (PP) volts**	**Gain in dB = 20*log(Vo/Vi)**	**Y_1**	**Y_2**	**Phase angle f (degrees)**

9	Sample Calculation	
10	Graphs, Outputs	
11	Results & Analysis	Thus, a passive RC lead compensating network was designed for the given specifications, like the maximum phase lead and the frequency at which it occurs and its frequency response characteristics were obtained.
12	Application Areas	
13	Remarks	
14	Faculty Signature with Date	

Experiment 05: DESIGN OF LAG NETWORK

-	**Experiment No.:**	5	**Marks**		**Date Planned**		**Date Conducted**	
1	Title	a) To design a passive RC lag compensating network for the given specifications,						

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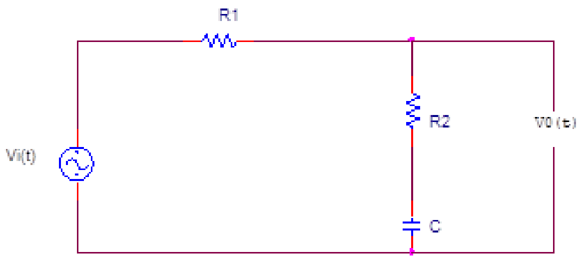
		viz, the maximum phase lag and the frequency at which it occurs and to obtain the frequency response. b) To determine experimentally the transfer function of the lag compensating network.
2	Course Outcomes	Design and analyse RC lag compensating network for given specifications
3	Aim	a) To design a passive RC lag compensating network for the given specifications, like the maximum phase lead and the frequency at which it occurs. a) To obtain its frequency response
4	Material / Equipment Required	Lag- lead unit, CRO, voltmeter 0-30V(MI), connecting wires.
5	Theory, Formula, Principle, Concept	A sinusoidal input is applied to the network and if its steady state output has a phase lag, then the network is called lag compensator network. This network has a **zero** at $s = 1 / (\beta T)$ and a pole at $s = 1/T$. Since the pole is closer to origin than zero, this compensator improves the steady state behavior of the system while nearly preserving its transient response. These compensators are used when low steady state error is required. The Low Pass Filter is also known as the phase lag controller since the corresponding phase introduced is negative. **Circuit diagram for deriving TF**:  **Design**: **Derivation of transfer function of the circuit**: After taking LT of the above circuit, we get $V_i(s) = (Z_1 + Z_2)\ I(s)$ Where $Z_1 = R_1$ and $Z_2 = R_2 + 1/(C_2 s)$ $V_o(s) = Z_2\ I(s)$ $TF = V_o(s) / V_i(s) = (Z_1 + Z_2) / Z_1$ After simplification we get the TF in the form of $TF = (s + 1/T) / (s + 1/(\beta T))$ where $\beta > 1$ WhereTime constant $T = R_2 C$ secs and $\beta = (R_1 + R_2) / R_2 > 1$ **Design equations:** $\beta = (1 + \sin\Phi_m) / (1 - \sin\Phi_m)$ (1) Let it be given that $\Phi_m = \sin^{-1}(1 - \beta / 1 + \beta)$ After substituting in equation (1) and simplifying we get $\beta = 2$ Also we have $\beta = (R_1 + R_2) / R_2$ (2) Let $R_2 = 10k\Omega$ and substitute in equation (2) $R_1 = 1k\Omega$ $C = 0.1\ \mu F$ Time constant $= T = R_2 C$ Frequency at which maximum phase lead occurs $\omega_m = 1 / (\sqrt{\beta})\ T$ rad / sec Corner frequency-1 $\omega_{c1} = 1 / \beta T$ rad / sec Corner frequency-2 $\omega_{c2} = 1/ (T)$ rad / sec Now $TF = (s + 1/T / (s + 1/(\beta T)) = (s + 100000) / (11s + 100000)$
6	Procedure,	1. A passive RC lag compensating network is designed and for the given

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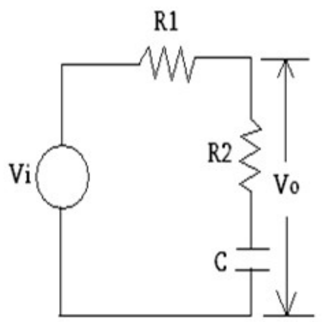
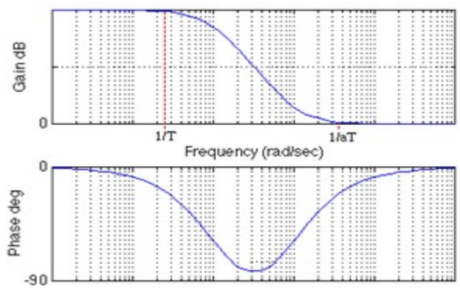
Program, Activity, Algorithm, Pseudo Code

specifications.

2. Connections are made as per the circuit diagram.
3. The output voltage of sine generator is set to 10 V (peak to peak) and is supplied as input to the RC lag compensator.
4. A CRO is connected at the output of the lag compensator.
5. The input frequency of the circuit is varied in steps and the corresponding output voltage is tabulated using CRO in every steps.
6. In addition to this, the phase angle is calculated using Lissajous figure in CRO.
7. The voltage gain is calculated using the formula as given in the table.
8. The plots of gain in dB Vs frequency and phase angle Vs frequency are plotted in semi log sheet.

7 Block, Circuit, Model Diagram, Reaction Equation, Expected Graph





8 Observation Table, Look-up Table, Output

Input voltage V_i =________________ volts (Peak-Peak)

S. No.	Frequency (Hz)	Output Voltage Vo (PP) volts	Gain in dB = 20*log(Vo/Vi)	Y_1	Y_2	Phase angle f (degrees)

9 Sample Calculation

10 Graphs, Outputs

11 Results & Analysis

Thus, a passive RC lag compensating network was designed for the given specifications, like the maximum phase lead and the frequency at which it occurs and its frequency response characteristics were obtained.

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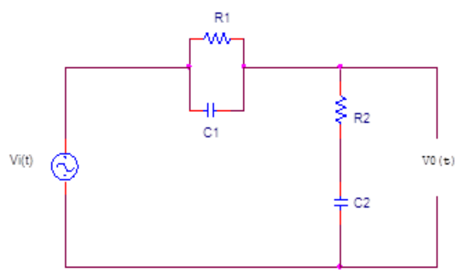
12	Application Areas	
13	Remarks	
14	Faculty Signature with Date	

Experiment 06: DESIGN OF LAG - LEAD NETWORK

-	Experiment No.:	6	Marks		Date Planned		Date Conducted	
1	Title	Experiment to draw the frequency response characteristics of the lag – lead compensator network and determination of its transfer function.						
2	Course Outcomes	Design and analyze Lag- Lead compensating network for given specifications						
3	Aim	Conduct an experiment to draw the frequency response characteristic of a given lag-lead compensating network.						
4	Material / Equipment Required	**Lag- lead unit, CRO, voltmeter 0 - 30V , connecting wires.**						
5	Theory, Formula, Principle, Concept	Lag-lead compensator is a combination of a lag compensator and lead compensator. The lag section has one real pole and one real zero, with pole to the right of zero. The lead section also has one real pole and one real zero, but zero is to the right of the pole. When both steady state and transient response require improvement, a lag – lead compensator is required. A compensator having the characteristic of lag-lead network is called lag-lead compensator. In a lead - lag network when sinusoidal signal is applied, both phase lag and phase lead occurs in the output but in different frequency region. Phase lag occurs in the lower frequency region and phase lead occurs in higher frequency region. A lead compensator basically increases bandwidth and speed up the response to decrease the maximum overshoot for the step response. Lag compensating increases lower frequency gain and thus improves the steady state accuracy of the system, but speed of the response will be reduced due to reduced band width. Lag - lead compensation network combines the advantages of lag and lead compensation. **Circuit diagram for deriving TF:** 						
6	Procedure, Program, Activity, Algorithm, Pseudo Code	1. The selector switch on the n/w is set either at lag, lead, lag-lead case. 2. The o/p voltage of the sine generator is connected to the n/w i/p terminals and with reference to phase meter 3. The o/p of sine generator and the o/p of the n/w terminals is connected to CRO to observe waveforms simultaneously. 4. The input voltage is set to the desired value and the frequency is varied						

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in steps. For a lead n/w vary the frequency of sine generator from 10Hz to 10KHz, For lag n/w, from 1Hz to 1KHz and For a lag-lead n/w from 1HZ to 10KHz respectively.

5. The o/p voltage Vo and i/p voltage Vi are noted down from CRO and corresponding phase angle from phase meter.
6. The magnitude in decibels is calculated as 20Log_{10} (Vo/Vi).
7. The magnitude and the phase angle plot (bode plot) is plotted on the semilog sheet.
8. Obtain the TF from the Bode plot drawn as follows:

Note down corner frequencies w1, w2, w3 and w4

TF= $(s+\omega_2)(s+\omega_3)/(s+\omega_1)(s+\omega_4)$

Transfer Function:

The selector switch on the n/w is set either at lag, lead, lag-lead case.

1. The o/p voltage of the sine generator is connected to the n/w i/p terminals and with reference to phase meter
2. The o/p of sine generator and the o/p of the n/w terminals is connected to CRO to observe waveforms simultaneously.
3. The input voltage is set to the desired value and the frequency is varied in steps. For a lead n/w vary the frequency of sine generator from 10Hz to 10KHz, For lag n/w, from 1Hz to 1KHz and For a lag-lead n/w from 1HZ to 10KHz respectively.
4. The o/p voltage Vo and i/p voltage Vi are noted down from CRO and corresponding phase angle from phase meter.
5. The magnitude in decibels is calculated as 20Log_{10} (Vo/Vi).
6. The magnitude and the phase angle plot (bode plot) is plotted on the semilog sheet.
7. Obtain the TF from the Bode plot drawn as follows:

Note down corner frequencies w1, w2, w3 and w4

TF= $(s+\omega_2)(s+\omega_3)/(s+\omega_1)(s+\omega_4)$

Transfer Function:

$$Z_1=\frac{R_1\frac{1}{C_1S}}{R_1+\frac{1}{C_1S}}=\frac{R_1}{R_1C_1S+1}$$

$$Z_2=R_2+\frac{1}{C_2s}=\frac{R_2C_2S+1}{C_2s}$$

$$\frac{E_O(s)}{E_1(s)}=\frac{Z_2}{Z_1+Z_2}=\frac{\frac{R_2C_2S+1}{C_2s}}{\frac{R_2C_2S+1}{C_2S}+\frac{R_1}{R_1C_1S+1}}$$

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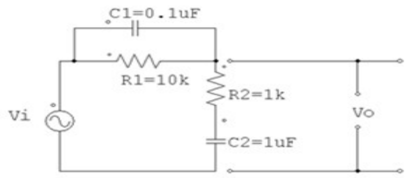
		$\frac{(R_2C_2S+1)(R_1C_1S+1)}{(R_2C_2S+1)(R_1C_1S+1)+R_1C_2S}$ $\frac{R_1R_2C_1C_2S^2+(R_1C_1+R_2C_2)S+1}{R_1R_2C_1C_2S^2+(R_1C_1+R_2C_2+R_1C_2)S+1}$ $TF=\frac{S^2+110KS+10^9}{S^2+210KS+10^9}$
7	Block, Circuit, Model Diagram, Reaction Equation, Expected Graph	
8	Observation Table, Look-up Table, Output	(see table below)

Frequency (Hz)	Phase Angle (Degrees)	I/P Voltage Vi(Volts)	O/P voltage Vo (Volts)	Gain = 20log(Vo/Vi) (db)

9	Sample Calculation	
10	Graphs, Outputs	
11	Results & Analysis	
12	Application Areas	
13	Remarks	
14	Faculty Signature with Date	

Experiment 07: STEP RESPONSE OF A SECOND-ORDER SYSTEM

-	Experiment No.:	7	Marks		Date Planned		Date Conducted	
1	Title	a) To simulate a typical second order system and determine step response and evaluate time response specifications. (b) To evaluate the effect of additional poles and zeros on time response of						

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		second order system. (c) To evaluate the effect of pole location on stability (d) To evaluate the effect of loop gain of a negative feedback system on stability.
2	Course Outcomes	Use MATLAB software package in assessing the time domain response of a given second order system.
3	Aim	Using MATLAB/SCILAB 1) Simulation of a typical second order system and determination of step response and evaluation of time- domain specifications. 2) Evaluation of the effect of additional poles and zeroes on time response of second order system. 3) Evaluation of effect of pole location on stability. 4) Effect of loop gain of a negative feedback system on stability.
4	Material / Equipment Required	PC loaded with MAT Lab
5	Theory, Formula, Principle, Concept	The total time response c(t) of control system consists of two parts. (i) Transient response Ctr(t) and (ii) Steady state response css(t). i.e., C(t) = Ctr(t) + Css(t). Most of the control systems use time as its independent variable. Analysis of response means to see the variation of output with respect to time. The output of the system takes some finite time to reach its final value. Every system has a tendency to oppose the oscillatory behavior of the system which is called damping. It is measured by a factor called damping ratio (ξ) of the system. If the damping is very high, then there will not be any oscillations in the output. The output is purely exponential. Such system is called an over damped ($1 < \xi < \infty$) system. If the damping is less is less compared to over damped case, then the system is called a critically damped (ξ=1) system. If the damping is very less, then the system is called under damped($0 < \xi < 1$) system. With no damping, the system is un damped(ξ =0). A series RLC circuit can be used to study the time response of a second order system. The voltage across the capacitor to a step input is analogous to step response of any II order system. **FORMULA USED:** **i)** <u>For under - damped system (x=0.2)</u> Assumption: ξ = 0.2, L= 200mH, C= 0.1uF $R=2\xi\sqrt{(L/C)}$, $L=CR^2/4\xi^2$, $C=4\xi^2L/R^2$, , $\sqrt{(1-\xi^2)}$ $M_p = e^{(-\Pi \xi / \sqrt{(1-\xi 2)})}$ $t_d=(1+0.7\xi)/$ $t_p = \Pi /$ where $= \sqrt{(1-\xi^2)}$ $tr = \Pi - \beta /$ where $\beta = \cos^{-1}\xi$ or $\beta=\tan^{-1} / \xi$

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		t_S= 4/ (ξ)
6	Procedure, Program, Activity, Algorithm, Pseudo Code	***<u>Common Procedure to all sub questions: -</u>*** 1. Open the MATLAB **command window**. Click on **New M-File** to open the MATLAB **editor window** and and type the program. 2. Save and run the program The graph is displayed. 3. Right click on the figure window and select grid to set grids on the curve. 4. Again right click on the figure window and select characteristics and click on peak response. We will get its value. 5. Again right click on the figure window and select characteristics and click on settling time.We will get its value. 6. Again right click on the figure window and select characteristics and click on rising time.We will get its value. 7. Tabulate the simulated value beside theoretical values and compare. 8. Repeat steps 5 to 9 for ξ = 0.1 (under damped), ξ = 1 (critically damped), ξ = 1.5 (over damped), ξ = 0 (un damped) and observe the time response. **a) Simulation of a typical second order system and determination of step response and evaluation of time- domain specifications.** **<u>For under - damped system (x=0.2)</u>** **PROGRAM: -** num = [0 0 50*10^6] den = [1 2828.42 50*10^6] step(num,den) grid title(' Unit step response of second order system') Ø Perform the calculation and write the program for ξ = 0.1 (under damped), ξ = 1 (critically damped), ξ = 1.5 (over damped), ξ = 0 (un damped) and observe the time response. 1. **For under - damped system (x=0.2)**

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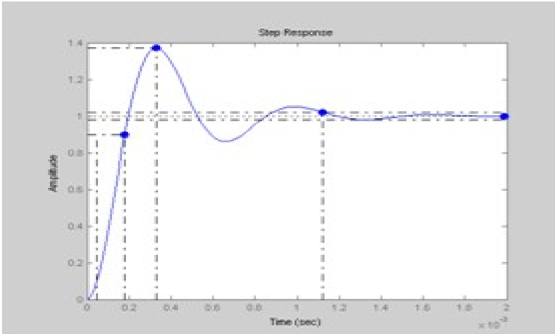
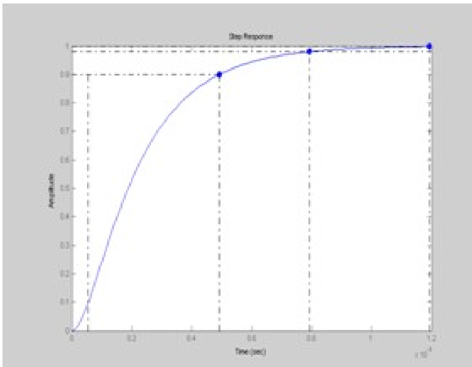
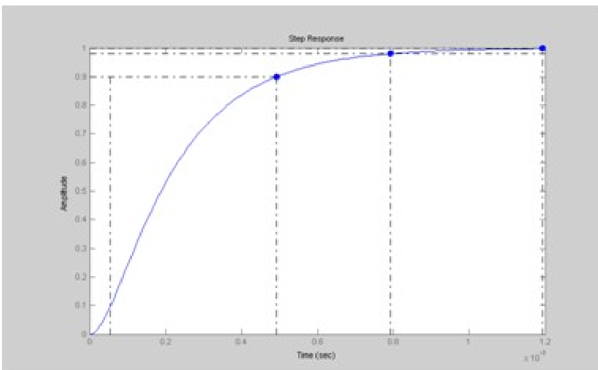
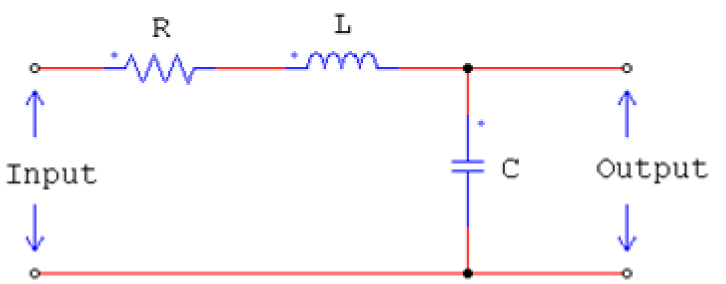


2. **For Critically - damped system (x=1)**



3. **For Over - damped system (x=1.2)**



7	Block, Circuit, Model Diagram, Reaction Equation,	

erved.

	Expected Graph	
8	Observation Table, Look-up Table, Output	<table><tr><th>S.N.</th><th>Time domain specifications</th><th>Theoretical values</th><th>Simulated values</th></tr><tr><td>1</td><td>tr (secs)</td><td></td><td></td></tr><tr><td>2</td><td>tp (secs)</td><td></td><td></td></tr><tr><td>3</td><td>ts (secs)</td><td></td><td></td></tr><tr><td>4</td><td>td (secs)</td><td></td><td></td></tr><tr><td>5</td><td>%Mp</td><td></td><td></td></tr></table>
9	Sample Calculation	
10	Graphs, Outputs	
11	Results & Analysis	Simulation of a typical second order system is simulated, the step response is determined and time-domain specifications are evaluated. It is seen that the simulated time-domain specifications are compared with theoretical values. Also it is observed that when $\xi = 0$ the oscillations will not die down. But as the damping ratio increases, the oscillations decreases and also time taken by the response decreases to reach its steady state value.
12	Application Areas	
13	Remarks	
14	Faculty Signature with Date	

Experiment 08: PID CONTROLLERS

-	Experiment No.:	8	Marks		Date Planned		Date Conducted	
1	Title	To simulate a second order system and study the effect of (a) P, (b) PI, (c) PD and (d) PID controller on the step response.						
2	Course Outcomes	To study the effect of P, PI, PD and PID controller on the step response of a feedback control system (using control engineering trainer/process control simulator) and Verifying the same by simulation.						
3	Aim	To simulate a second order system and study the effect of (a) P, (b) PI, (c) PD and (d) PID controller on the step response.						
4	Material /	Set point generator, PID controller unit, system simulator second order system.						

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	Equipment Required	PC loaded with MAT Lab
5	Theory, Formula, Principle, Concept	PID controllers are commercially successful and widely used in industries. For example, in a typical paper mill, there may be about 1500 controllers. Out of these 1500, 90% would be PID controllers. The PID controller consists of Proportional controller, Integral controller and Derivative controller. Depending upon the application, one or more combination of the controllers is used. Example: In a liquid control system, where we want zero steady state error, a PI controller can be used. In a temperature control system, where where we do not want zero steady state reeor, a simple P controller can be used. The output m(t) of the PID controller in time domain is given by; m(t) = Kp e(t) + Ki/Ti ∫ e(t) dt + KdTdde(t)/dt Where Kp, Ki, Kd = Proportional, integral, differential gains Ti, Td= Integral, derivative times of PID controller e(t) = r(t) – c(t) Where e(t), r(t), c(t)= error, reference, output signals **The characteristics of P, I and D controllers:** Effect of each of controllers Kp, Ki and Kd on a closed loop system are summarized in the following table.

CL Response	Rise time	Overshoot	Settling time
Kp	Decrease	Increase	Small change
Ki	Decrease	Increase	Increase
Kd	Small change	Decrease	Decrease

6	Procedure, Program, Activity, Algorithm, Pseudo Code	Connect the speed sensor to the socket provided. 1. Connect the motor to corresponding terminals. 2. Switch on P controller. 3. Set required speed using set pointer. This is displaced in digital tachometer. 4. Now load the motor in steps of 50gms upto 250 gms using the given load on the loading arrangement. 5. Observe the speed of the motor and take the reading. 6. Now switch on P & I controller. 7. Repeat step 4 & 6. 8. Now switch ON P,I & D controller. 9. Plot the graph of load vs speed on the graph sheet for PID controller. clc clear all Num=input('The Numerator co-efficients of the given transfer function are ='); Den= input('The Denominator co-efficients of the given transfer function are ='); G=tf(Num,Den)

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<table>
<tr><td></td><td></td><td>step(G);</td></tr>
<tr><td>7</td><td>Block, Circuit, Model Diagram, Reaction Equation, Expected Graph</td><td></td></tr>
<tr><td>8</td><td>Observation Table, Look-up Table, Output</td><td>
P-CONTROLLER:
<table>
<tr><th>SET SPEED</th><th>WEIGHT</th><th>RUN SPEED</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>
PI CONTROLLER
<table>
<tr><th>SET SPEED</th><th>WEIGHT</th><th>RUN SPEED</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td></tr>
</table>
PID CONTROLLER:
<table>
<tr><th>SET SPEED</th><th>WEIGHT</th><th>RUN SPEED</th></tr>
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<tr><td></td><td></td><td></td></tr>
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9	Sample Calculation	
10	Graphs, Outputs	
11	Results & Analysis	The effect of P, PI, PD and PID controllers on the step response of a feedback control system was studied and the response curves of them were drawn respectively.
12	Application Areas	
13	Remarks	
14	Faculty Signature with Date	

Experiment 09: POSITION CONTROL SYSTEM: DC SERVOMOTOR

-	**Experiment No.:**	9	**Marks**		**Date Planned**		**Date Conducted**	
1	Title	(a)To simulate a D. C. position control system and obtain its step response. b) To verify the effect of the input wave form, loop gain system type on steady state errors. c) To perform a trade-off study for lead compensation d) To design a PI controller and study its effect on steady state error.						
2	Course Outcomes	Simulate a DC position control system using MATLAB and obtain its step response and to design PI controller and study its effect on steady state error.						
3	Aim	Using MATLAB/SCILAB a) Simulate a D. C. position control system and obtain its step response. b) To verify the effect of the input wave form, loop gain system type on steady state errors. c) To perform a trade-off study for lead compensation d) To design a PI controller and study its effect on steady state error						
4	Material / Equipment	PC loaded with MATLAB						

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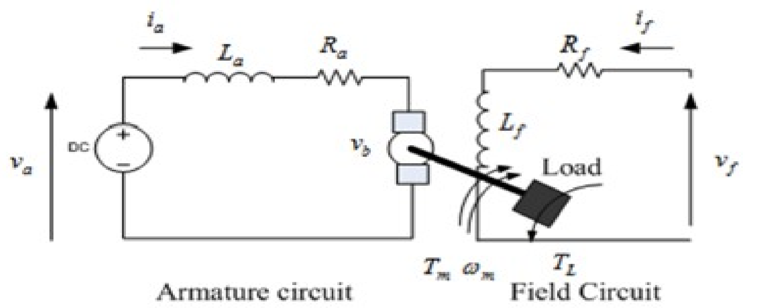
	Required	
5	Theory, Formula, Principle, Concept	**a) Simulate a D. C. position control system and obtain its step response.**

Consider the armature-controlled dc servomotor shown below:

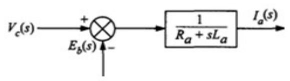


Applying KVL to the armature loop, we get

$$R_a\, i_a + e_b(t) = v(t)$$

Taking Laplace transform on both the sides of the above equation with all initial conditions set to zero, we get

$R_a\, I_a(s) + sL_a I_a(s) + E_b(s) = Va(s)$



Translating the above equation into a block diagram, we get

The torque T(t) developed by the motor is proportional to the product of the e and field currents.

$$\text{i.e. } T(t)\ \alpha\ i_a(t)\, i_f(t)$$

$$T(t)\ \alpha\ i_a(t) \text{ (since } i_f \text{ is constant)}$$

$$T(t) = K_T\, i_a(t)$$

where K_T is the constant of proportionality known as the torque constant of the motor

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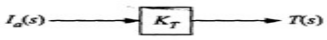
and is expressed in N-m/A.
Taking Laplace transform on both the sides of the above equation, we get

$T(s) = K_T I_a(s)$

Translating the above equation into a block diagram,



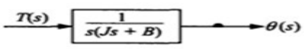
The torque produced by the motor must be balanced by the load torque

$$T(t) = T_L(t)$$

$$T(t) = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt}$$

Taking Laplace transform of the immediate above equation, we get
$T(s) = Js^2\theta(s) + Bs\theta(s)$

$$\theta(s) = \frac{T(s)}{s(Js+B)}$$



Translating the above equation into a block diagram, we get
The back emf of the motor is directly proportional to the angular velocity of the motor.

$$e_b(t)\,\alpha\,\frac{d\theta}{dt}$$

$e_b(t) =$ 

where Kb is the constant of proportionality known as the back emf constant of the motor and is expressed in V/rad/sec.

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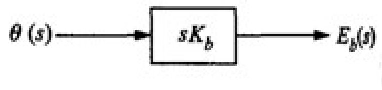
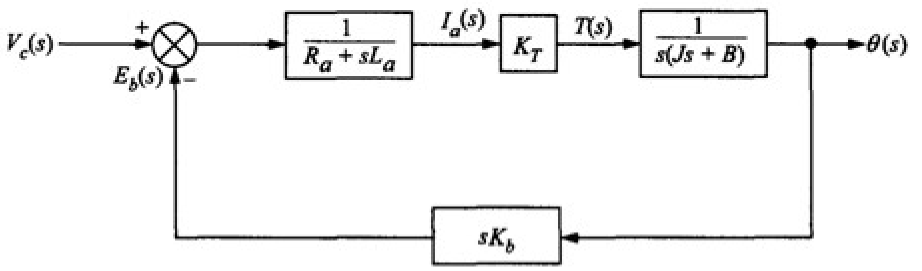
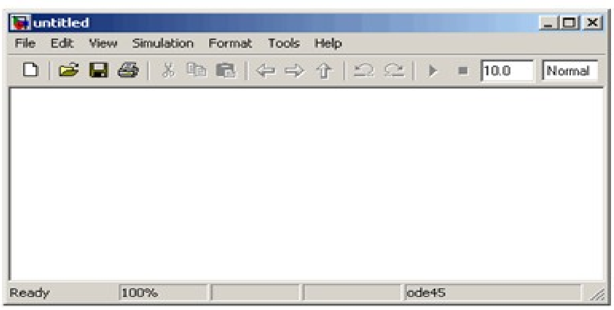
		Taking Laplace transform on both the sides of the immediate above equation, we get $E_b(s) = K_b\, s\, \theta(s)$  The overall block diagram of the motor is as shown below.
6	Procedure, Program, Activity, Algorithm, Pseudo Code	**1.** ... ry  Al Cl Or Clicking the MATLAB Start button, then selecting Simulink Library Browser 

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3. To open an existing model:

Select File à Open in the Simulink Library Browser. The Open dialog box appears.

Select the model (.mdl file) you want to open, and then click Open. The software opens the selected model in the model window.

4. Simulink® Library Browser:

The Library Browser displays the Simulink® block libraries installed on your system. You build models by copying blocks from a library into a model window.

- **To view the blocks in a library, select the library name on the left side of the Library Browser, or double-click on the library.**

  - When you select a block, a description of that block appears at the bottom of the browser.
  - For more information on a block, select the block, then select Help à Help on the Selected Block to display the help page for the block.
  - To view the parameters for a block, right-click the block, then select Block Parameters.

To search for a specific block, enter the name of the block in the block search field and then click on the Find block icon

a) To verify the effect of the input wave form, loop gain system type on steady state errors.

```
% G1(s)=1/s^3 + 3 s^2 + 7 s + 1

% G2(s)=1/s(s+1)(s+2)
```


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```
% G3(s)=1/s^2(s+0.2)

num1=[2];

num2=[1];

num3=[100];

den1=[1 3 7 2 ];

den2=[1 3 2 1];

den3=[1 10 0 100]

h1=tf(num1,den1)

h2=tf(num2,den2)

h3=tf(num3,den3)

hold

step(h1,h2)

% step(h3)

legend('Type 0 system','Type 1 system ','Type 2 system')

% axis([0 18 0 1.4])
```

b) To perform a trade-off study for lead compensation

Consider a system with OLTF

It is desired to design a lead compensator for the system so that the static velocity error constant Kv = 20/sec, the phase margin is at least 50^{0} and the gain margin is at least 10dB.

Let us consider a compensator of the form

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The compensated system will have the open loop transfer function

Define   Where

<u>To adjust gain K to meet steady state performance specifications:</u>

Given K_V = 20/sec,

Solving we get K =10

<u>To obtain bode plot:</u>

G_1 (s)= K_c α G(s)=KG(s)= 40/s(s+2)

From the plot, Phase margin = +18^{0} and gain margin = +¥.

The phase margin requirement is 50^{0}. We thus find the additional phase lead necessary to satisfy the relative stability requirement is 32^{0}. Let the maximum phase lead required is 37^{0}.

Since

$$sin\varphi_m = \frac{1-\alpha}{1+\alpha}$$

= 37^{0} corresponds to attenuation factor a = 0.24

To determine the corner frequencies 1/T and 1/αT

THe amount of modification in the magnitude curve at due to inclusion of the term

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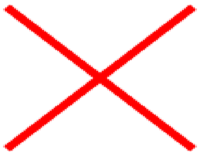

$$\left|\frac{Ts+1}{\alpha Ts+1}\right| = \left|\frac{j\omega T+1}{j\omega\alpha T+1}\right|_{\omega=\frac{1}{\sqrt{\alpha}T}} = \left|\frac{1+j\frac{1}{\sqrt{\alpha}}}{1+j\alpha\frac{1}{\sqrt{\alpha}}}\right| = \frac{1}{\sqrt{\alpha}}$$

$\frac{1}{\sqrt{\alpha}} = \frac{1}{\sqrt{0.24}} = ¿¿$ =6.2dB

and $|G_1(j\omega)|$ = -6.2 dB corresponds to ω = 9 rad / sec. this is the new gain crossover frequency or

$\omega_c = \frac{1}{\sqrt{\alpha}T}$ =9

hence

$$\frac{1}{T} = \sqrt{\alpha}\,\omega_c = 4.41$$

$$\frac{1}{\alpha T} = \frac{\omega_c}{\sqrt{\alpha}} = 18.4$$

The lead compensator thus determined is

$$G_c(s) = K_c\frac{s+4.41}{s+18.4}$$

Where $K_c = \frac{K}{\alpha} = \frac{10}{0.24} = 41.7$

Thus the transfer function of compensator becomes

$$G_c(s) = 41.7\frac{s+4.41}{s+18.4}$$

And the open loop transfer function of compensated system is

$$G_c(s)\cdot G(s) = 41.7\frac{s+4.41}{s+18.4}\,\frac{4}{s(s+2)}$$

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Program 1:

```
num1=[4];

den1=[1 2 4];

h1=tf(num1,den1);

num2=[166.8 735.588];

den2=[1 20.4 203.6 735.588];

h2=tf(num2,den2);

step(h1,h2)

legend('uncompensated system','compensated system')
```

Program 2:

```
num1=[4];

den1=[1 2 4 0];

h1=tf(num1,den1);

 num2=[166.8 735.588];

den2=[1 20.4 203.6 735.588 0];

h2=tf(num2,den2);

 step(h1,h2)

legend('uncompensated systen','compensated system')

axis([0 5 0 5])

title('Unit ramp responses of uncompensated and compensated system')
```

d) To design a PI controller and study its effect on steady state error

Program 1:

```
% Kp=1;
```


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```
% G=1/s(s+1.4),

H=1, Kp+Ki/s

clc;clear;

ki1=0.1;ki2=0.2;ki3=0.3;

num1=[1 ki1];

num2=[1 ki2];

num3=[1 ki3];

den1=[1 1.4 1 ki1];

den2=[1 1.4 1 ki2];

den3=[1 1.4 1 ki3];

 h1=tf(num1,den1);

h2=tf(num2,den2);

h3=tf(num3,den3);

step(h1,h2, h3);

legend('ki=0.1','ki=0.2', 'ki=0.5')
```

Program 2:

```
% Kp=1;

% G=1/s(s+1.4), H=1, Kp+Ki/s

clc;

clear;

t=0:0.01:30;

kp=1

kv=[0.1 0.2 0.3];

yv=[];

for i=1:3

    ki=kv(i);
```


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		`TF=tf([kp ki],[1 1.4 kp ki])`
		`[y,x]=step(TF,t);`
		`step(TF,t)`
		`hold on`
		`yv=[yv,y];`
		`end`
		`legend('ki=0.1','ki=0.2','ki=0.3');`

7	Block, Circuit, Model Diagram, Reaction Equation, Expected Graph	**Given:** J=3.2284e-6; B=3.5077e-6; Kt=0.0274; Kb=0.0274; La=2.75e-6; Ra=4; **Open Loop:** **Closed Loop:** **Subsystem:**

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8	Observation Table, Look-up Table, Output	
9	Sample Calculation	
10	Graphs, Outputs	
11	Results & Analysis	
12	Application Areas	
13	Remarks	
14	Faculty Signature with Date	

Experiment 10: Root Locus

-	Experiment No.:	10	Marks		Date Planned		Date Conducted	
1	Title	1) To examine the relationships between open-loop frequency response and stability, open loop frequency and closed loop transient response. 2) To study the effect of open loop gain on transient response of closed loop system using root locus.						
2	Course Outcomes	To analyse the relationship between open-loop frequency response and stability, open-loop frequency and closed loop transient response and to study the effect of open loop gain using root locus						
3	Aim	Using MATLAB/SCILAB 1. To examine the relationships between open-loop frequency response and stability, open loop frequency and closed loop transient response. 2. To study the effect of open loop gain on transient response of closed loop system using root locus.						
4	Material / Equipment Required	PC Loaded with MATLAB						
5	Theory, Formula, Principle, Concept							
6	Procedure, Program, Activity, Algorithm, Pseudo Code	1. Click on MATLAB 7.6 to start the program 2. Click on new file and give the file name and type the program. 3. Save and run the program **PROGRAM1:** clc; clear; zv=[0.5 1 2 10 inf];						

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```
t=[0:0.1:5];
omega_n=1;
zeta=0.7;
yv=[];
for i=1:5
    z=zv(i);
    G=tf([omega_n^2/z omega_n^2],[1 2*zeta*omega_n omega_n^2]);
    [y,x]=step(G,t);
    yv=[yv,y];
end
plot(t,yv(:,1),t,yv(:,2),t,yv(:,3),t,yv(:,4),t,yv(:,5));
grid;
legend('z=0.5','z=1','z=2','z=10','z=\infty');
```

PROGRAM2:

```
clc;
clear;
zv=[0.5 1 2 10 inf];
t=[0:0.1:15];
omega_n=1;
zeta=0.3;
yv=[];
for         i=1:5
    z=zv(i);
    G=tf([omega_n^2/z omega_n^2],[1 2*zeta*omega_n omega_n^2]);
    [y,x]=step(G,t);
    yv=[yv,y];
```


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```
end

plot(t,yv(:,1),t,yv(:,2),t,yv(:,3),t,yv(:,4),t,yv(:,5));

grid;

legend('z=0.5','z=1','z=2','z=10','z=\infty');
```

PROGRAM3:

```
clc;
clear;
zv=[-0.5 -1 -2 -10 -inf];
t=[0:0.1:15];
omega_n=1;
zeta=0.3;
yv=[];
for i=1:5
z=zv(i);
G=tf([omega_n^2/z omega_n^2],[1 2*zeta*omega_n omega_n^2]);
[y,x]=step(G,t);
yv=[yv,y];
end
 plot(t,yv(:,1),t,yv(:,2),t,yv(:,3),t,yv(:,4),t,yv(:,5));
grid;
legend('z=-0.5','z=-1','z=-2','z=-10','z=\-infty');
```

PROGRAM4:

```
clc;

clear;

zv=[-0.5 -1 -2 -10 -inf];

t=[0:0.1:5];

omega_n=1;

zeta=0.7;
```


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```
yv=[];
for i=1:5
z=zv(i);
G=tf([omega_n^2/z omega_n^2],[1 2*zeta*omega_n omega_n^2]);
[y,x]=step(G,t);
yv=[yv,y];
end
 plot(t,yv(:,1),t,yv(:,2),t,yv(:,3),t,yv(:,4),t,yv(:,5));
grid;
legend('z=-0.5','z=-1','z=-2','z=-10','z=-\infty');
```

i) The effect of an additional closed loop pole

PROGRAM1:

```
clc; clear;
pv=[0.1 .5 2 10 inf];
t=[0:.3:15];
omega_n=1;
zeta=0.7;
yv=[];
for i=1:5
   p=pv(i);
   G=tf(omega_n^2,conv([1/p 1],[1 2*zeta*omega_n omega_n^2]));
   [y,x]=step(G,t);
   yv=[yv,y];
end
plot(t,yv(:,1),t,yv(:,2),t,yv(:,3),t,yv(:,4),t,yv(:,5));
```


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```
grid;
legend('p=0.1','p=0.5','p=2','p=10','p=\infty');
```

PROGRAM2:

```
clc; clear;
pv=[0.1 .5 2 5 inf];
t=[0:.01:15];
omega_n=1;
zeta=0.3;
yv=[];
for i=1:5
    p=pv(i);
    G=tf(omega_n^2,conv([1/p 1],[1 2*zeta*omega_n omega_n^2]));
    [y,x]=step(G,t);
    yv=[yv,y];
end
plot(t,yv(:,1),t,yv(:,2),t,yv(:,3),t,yv(:,4),t,yv(:,5));
grid;
legend('p=0.1','p=0.5','p=2','p=10','p=\infty');
```


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7	Block, Circuit, Model Diagram, Reaction Equation, Expected Graph	
8	Observation Table, Look-up Table, Output	
9	Sample Calculation	
10	Graphs, Outputs	
11	Results & Analysis	The response of a dominantly second order system is sped up by an additional zero and is slowed down by an additional pole. In the dominantly second-order system the added closed loop zero also has the important effect of increasing the amount of oscillation in the system while an added closed loop pole has the effect of decreasing the amount of oscillation. Added forward path zeros and added forward path poles have an opposite effect on the overshoot. A forward path pole which is too close to the origin may turn the closed loop system unstable. A right half-plane zero also causes a `wrong way' response. All effects become more pronounced as the additional zero or pole approach the origin and become dominant.
12	Application Areas	
13	Remarks	
14	Faculty Signature with Date	

Experiment 11: STABILITY STUDY

-	Experiment No.:	11	Marks		Date Planned		Date Conducted	
1	Title	1. To study the effect of open loop poles and zeros on root locus contour 2. To estimate the effect of open loop gain on the transient response of closed loop system using root locus. 3. Comparative study of Bode, Nyquist and root locus with respect to stability.						
2	Course Outcomes	Write a script files to plot root locus, bode plot, Nyquist plots to study the stability of the system using a software						
3	Aim	Using MATLAB/SCILAB a. Effect of open loop poles and zeroes on root locus contour b. To estimate the effect of open loop gain on the transient response of closed loop system by using Root Locus						

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		c. Comparative study of Bode, Nyquist and Root locus with respect to Stability.
4	Material / Equipment Required	
5	Theory, Formula, Principle, Concept	
6	Procedure, Program, Activity, Algorithm, Pseudo Code	1. Click on the MATLAB7.1icon on monitor to start the program 2. Click on mfile and give the file name and type the program 3. Save and run the programs

a) Effect of open loop poles on root locus contour

Consider the open loop transfer function

$$G(s)H(s)=\frac{K}{s(s+a)}$$

The closed loop transfer function will be

$$\frac{C(s)}{R(s)}=\frac{K}{s^2+as+K}$$

or

$$G(s)H(s)=\frac{as}{s^2+as+K}$$

Program:

```
clc;
clear;
kv= [1 4 9 16]
for i=1:4
   k=kv(i)
   num=[1 0];
   den=[1 0 k];
   rlocus(num,den)
   hold on
end
```

Program:

```
clc;
clear;
kv= [1 4 9 16]
for i=1:4
   k=kv(i)
   num=[1 0];
   den=[1 0 k];
```


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```
   rlocus(num,den)
   hold on
end
```

a) Comparative study of Bode, Nyquist and Root locus with respect to Stability.

I) $TF = \frac{1}{s^2+3s+2}$

PROGRAM

```
clc;

clear;

num = [1]

den = [1 3 2]

H = tf(num,den)

figure(1)

bode(H)

margin(H)

figure(2)

rlocus(H)

figure(3)

nyquist(H)
```


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2)

$$TF=\frac{1}{s^2-4s+8}$$

PROGRAM 2:

```
clc;
clear;
num = [1 0]
den = [1 -4 8]
H = tf(num,den)
figure(1)
bode(H)
margin(H)
figure(2)
```


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		rlocus(H) figure(3) nyquist(H)
7	Block, Circuit, Model Diagram, Reaction Equation, Expected Graph	
8	Observation Table, Look-up Table, Output	
9	Sample Calculation	
10	Graphs, Outputs	
11	Results & Analysis	
12	Application Areas	
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14	Faculty Signature with Date	

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F. Content to Experiment Outcomes

1. TLPA Parameters

Table 1: TLPA – Example Course

Expt-#	Course Content or Syllabus (Split module content into 2 parts which have similar concepts)	Content Teaching Hours	Blooms' Learning Levels for Content	Final Blooms' Level	Identified Action Verbs for Learning	Instruction Methods for Learning	Assessment Methods to Measure Learning
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
1	Write a C++ program to read series of names, one per line, from standard input and write these names spelled in reverse order to the standard output using I/O redirection and pipes. Repeat the exercise using an input file specified by the user instead of the standard input and using an output file specified by the user instead of the standard output.	3	- L2 - L3 - L4	L4	- -	- Lecture - -	- Slip Test - -
2	Write a C++ program to read and write student objects with fixed length records and the fields delimited by "|". Implement pack ( ), unpack ( ), modify ( ) and search ( ) methods.	3	- L2 - L3 - L4	L4	- -	- Lecture - Tutorial -	- Assignment - -
3	Write a C++ program to read and write student objects with Variable - Length records using any suitable record structure. Implement pack ( ), unpack ( ), modify ( ) and search ( ) methods.	3	- L2 - L3 - L4	L4	- -	- Lecture -	- Assignment -
4	Write a C++ program to write student objects with Variable - Length records using any suitable record structure and to read from this file a student record using RRN.	3	- L2 - L3 - L4	L4	- -	- Lecture -	- Slip Test -
5	Write a C++ program to implement simple index on primary key for a file of student objects. Implement add ( ), search ( ), delete ( ) using the index.	3	- L2 - L3 - L4	L4	- -	- Lecture -	- Slip Test -

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6	Write a C++ program to implement index on secondary key, the name, for a file of student objects. Implement add ( ), search ( ), delete ( ) using the secondary index.	3	- L2 - L3 - L4	L4	- -	- Lecture - Tutorial -	- Assignment - -
7	Write a C++ program to read two lists of names and then match the names in the two lists using Co Sequential Match based on a single loop. Output the names common to both the lists.	3	- L2 - L3 - L4	L4	- -	- Lecture - Tutorial -	- Assignment - -
8	Write a C++ program to read k Lists of names and merge them using k-way merge algorithm with k = 8.	3	- L2 - L3 - L4	L4	- -	- Lecture - Tutorial -	- Assignment - -
9	Student should develop mini Project on the topics mentioned below or similar applications Document processing, transaction management, indexing and hashing, buffer management, configuration management. Not limited to these.	3	- L2 - L3 - L4	L4	- -	- Lecture - -	- Assignment - -

2. Concepts and Outcomes:

Table 2: Concept to Outcome – Example Course

Expt - #	Learning or Outcome from study of the Content or Syllabus	Identified Concepts from Content	Final Concept	Concept Justification (What all Learning Happened from the study of Content / Syllabus. A short word for learning or outcome)	CO Components (1.Action Verb, 2.Knowledge, 3.Condition / Methodology, 4.Benchmark)	Course Outcome **Student Should be able to ...**
A	*I*	*J*	*K*	*L*	*M*	*N*
1	- -	- -	Klystron oscillator	Comprehend the working of Klystron oscillator	- Understand - Klystron Oscillator - -	Understand the working of Klystron Oscillator.
2	- -	- -	Microwave transmission lines	Examine the transmission lines using graphical methods	- Analyze - Transmission Lines - Graphical Methods -	Analyze the transmission lines using Graphical methods.
3	- -	- -	Multiport networks	Implement the Z, Y and S parameters to Multiport networks	- Analyze - Multiport Networks - -	Analyze the Z, Y and S parameters for a Multiport network.
4	- -	- -	Microwave passive devices	Understand the working of microwave passive devices	- Understand - Microwave Passive Devices - -	Understand the working of different microwave passive devices.
5	- -	- -	Striplines	Have knowledge of micro, parallel and shielded striplines	- Understand - Types of Stripline - -	Understand micro, parallel and shielded striplines.
6	- -	- -	Antenna parameters	Compute the antenna design characteristics using the parameters	- Apply - Design Characteristics - -	Describe antenna working using the given parameters.
7	- -	- -	Array of point sources	Extend the antenna parameters to the array of point sources	- Apply - Array of Point Sources - -	Describe the working of point sources.

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8	- -	- -	Electric dipole antennas	Examine the field parameters of electric dipole antennas	- Analyze - Electric Dipole Antenna	Analyze the working of electric dipole antenna.
9	- -	- -	Loop and horn antennas	Explain the working of horn and loop antennas	- Understand - Horn and Loop Antenna	Explain the working of horn and loop antennas.

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