

ABET COURSE BINDER

**ROY G. PERRY COLLEGE OF ENGINEERING
ELECTRICAL AND COMPUTER ENGINEERING
DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**

ASSESSMENT REPORT COVER PAGE

**ELEG 4307 SERVOMECHANICS AND
CONTROL SYSTEMS**

SPRING 2022 SEMESTER

NAME OF INSTRUCTOR: Sarhan Musa

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 - 5.1 Assignments assessing students' ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors (outcome 2)

Detailed Course Syllabus
(Distributed to Students at the beginning of the Semester)

Course Title: Servomechanism and Control Systems		
Course Prefix: ELEG Course No.: 4307 Section No.: P01		
Department: Electrical and Computer Engineering Department		
College: Roy G. Perry College of Engineering		
U.S. Postal Service Address:	Prairie View A&M University P.O. Box 519 Mail Stop 2520 Prairie View, TX 77446	
Instructor Name:	Sarhan M. Musa	
Office Location:	Electrical Engineering Building (NENGR BLDG), Room 328	
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Email Address:	smmusa@pvamu.edu	
Office Hours:	MF T W	9:00 am - 10:00 am; 11:00 am - 12:00 pm 5:00 pm - 6:00 pm 9:00 - 10:00 am
	<i>or by appointment</i>	
Virtual Office Hours:	By email	
Course Location:	New Electrical Engineering Building (NENR), Room 117	
Class Meeting Days & Times:	M, W, F 11:00 am -11:50 am	
Catalog Description:	ELEG 4073 Servomechanism and Control Systems: (3-0) Credit 3 semester hours. Model of physical systems, system responses, system characteristics, stability design, frequency response analysis and design, discrete-time systems.	
Prerequisites:	ELEG 3023 (Signals and Systems) and MATH 4173 (Advanced Math for Engineers)	
Co-requisites	None	
Requirement Text	N. S. Nise, “Control Systems Engineering,” 8 th edition. Wiley Publisher (2019), ISBN: 978-1-119-47422-7	
Recommended Text/Readings:	(1) B. C. Kuo, “Automatic Control Systems,” Prentice Hall, 7 th ed. (2) R. C. Dorf and R. H. Bishop, “Modern Control Systems,” Prentice Hall; 10 th ed.	
Access to Learning Resources:	PVAMU Library: phone: (936) 261-1542; web: https://www.pvamu.edu/library/ University Bookstore: phone: (936) 261-1990; web: https://www.bkstr.com/prairieviewamunivstore/home	
Course Goals or Overview:	This is a course in servomechanism and control systems, which will introduce students to the theory and practice of control systems engineering. The course will also emphasize on the practical application of the subject to the analysis and design of feedback systems. The lecture topics will include: modeling of open-loop systems, using frequency response techniques and state-space techniques, respectively; finding and describing the output response of a system, stability, steady-state errors, and transient response of higher-order systems using root locus techniques, design of compensators and controllers using the root locus, sinusoidal frequency analysis and design, Nyquist and Bode methods, state-space design and digital control systems analysis and design. In addition, the use	

	of MATLAB/ LabVIEW for servomechanism and control systems will be covered.	
Course Outcomes/Objectives	At the end of this course, the student will: 1. Be able to understand the simplification of servomechanism and control systems block diagrams and obtain the closed-loop transfer function 2. Be able to recognize and analyze the stability of servomechanism and control systems with characteristic equation, using the Routh-Hurwitz criterion. 3. Be able to understand the maximum percent overshoot (MPO) for the transfer functions 4. Be conversant with over damped, critical damped, under damped, or no damped for the servomechanism and control systems 5. Be able to design, construct, test a root-locus diagram of the of servomechanism and control systems with open-loop transfer function 6. Be able to use MATLAB or LABVIEW to solve servomechanism and control' problems.	
ABET Program Outcomes (ABET Criterion 3, Student Outcome 2):	On completion of course the student should have demonstrated an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	
Class Participation	Daily attendance and participation in class discussions	
Assignments:	Written assignments designed to supplement and reinforce course material. Problems on the topics discussed in class will be assigned. Assignments should be completed and handed in <u>on time</u> . Late homework will not be accepted. Dates will be announced.	
Quizzes:	Written quizzes designed to supplement and reinforce course material. Dates will be announced.	
Computer Application Problems:	There will be computer applications problems that will involve the use of the MATLAB (The MathWorks, Inc.) and/or LABVIEW (National Instruments Corporation) for solving Servomechanism and Control Systems. Dates will be announced.	
Course Design Project:	You will be asked to design a servomechanism /control system that meets some specifications. A design project report is also required. The report should include, among other things, the block diagram, component values, and design equations, testing methodology, test results and conclusions. Dates will be announced.	
Exams/Tests:	Written tests designed to measure knowledge of presented course material. Dates will be announced.	
Course Evaluation Procedure: The final grade of each student will be determined by the following weights		
	Item	Value (percentage)
	Attendance & Participation	5%
	Assignments/Quizzes/Projects	35%
	Exams (3 exams; 20% each)	60%
	Total:	100%

	Grade Determination: A = 90% – 100%; B = 80% – 89%; C = 70%– 79%; D = 60% – 69%; F = below 60%.
Topics Covered	
The course will cover the following materials (a tentative outline is given below; however, the exact time spent on a subject may vary):	
Week 1: Introduction, System Configurations, Analysis and Design Objectives, Design Process	
Week 2: Modeling in Frequency Domain	
Week 3: Modeling in Time Domain	
Week 4: Time Response	
Week 5: Reduction of Multiple Subsystems	
Week 6: Stability	
Week 7: Steady-State Errors	
Week 8: Root Locus Techniques	
Week 9*: Spring Break	
Week 10: Design via Root Locus	
Week 11: Frequency Response Techniques	
Week 12: Design via Frequency Response	
Week 13: Design via State Space	
Week 14: Robust Control System	
Week 15: Digital Control Systems	

University Rules and Procedures	
Disability statement (See Student Handbook): Students with disabilities, including learning disabilities, who wish to request accommodations in class should register with the Services for Students with Disabilities (SSD) early in the semester so that appropriate arrangements may be made. In accordance with federal laws, a student requesting special accommodations must provide documentation of their disability to the SSD coordinator.	
Academic misconduct (See Student Handbook): You are expected to practice academic honesty in every aspect of this course and all other courses. Make sure you are familiar with your Student Handbook, especially the section on academic misconduct. Students who engage in academic misconduct are subject to university disciplinary procedures.	
Forms of academic dishonesty: 1. Cheating: deception in which a student misrepresents that he/she has mastered information on an academic exercise that he/she has not mastered; giving or receiving aid unauthorized by the instructor on assignments or examinations. 2. Academic misconduct: tampering with grades or taking part in obtaining or distributing any part of a scheduled test. 3. Fabrication: use of invented information or falsified research. 4. Plagiarism: unacknowledged quotation and/or paraphrase of someone else's words, ideas, or data as one's own in work submitted for credit. Failure to identify information or essays from the Internet and submitting them as one's own work also constitutes plagiarism.	
Nonacademic misconduct (See Student Handbook): The university respects the rights of instructors to teach and students to learn. Maintenance of these rights requires campus conditions that do not impede their exercise. Campus behavior that interferes with	

either (1) the instructor's ability to conduct the class, (2) the inability of other students to profit from the instructional program, or (3) campus behavior that interferes with the rights of others will not be tolerated. An individual engaging in such disruptive behavior may be subject to disciplinary action. Such incidents will be adjudicated by the Dean of Students under nonacademic procedures.

Sexual misconduct (See Student Handbook):

Sexual harassment of students and employers at Prairie View A&M University is unacceptable and will not be tolerated. Any member of the university community violating this policy will be subject to disciplinary action.

Attendance Policy:

Prairie View A&M University requires regular class attendance. Excessive absences will result in lowered grades. Excessive absenteeism, whether excused or unexcused, may result in a student's course grade being reduced or in assignment of a grade of "F". Absences are accumulated beginning with the first day of class.

Student Academic Appeals Process:

Authority and responsibility for assigning grades to students rests with the faculty. However, in those instances where students believe that miscommunication, errors, or unfairness of any kind may have adversely affected the instructor's assessment of their academic performance, the student has a right to appeal by the procedure listed in the Undergraduate Catalog and by doing so within thirty days of receiving the grade or experiencing any other problematic academic event that prompted the complaint.

College of Engineering Textbook Policy

Students must acquire the textbook that is listed as "required" on the course syllabus. The textbook must be acquired by the 10th class day. Students are not allowed to share textbooks with other students who are currently registered in the same class. Failure to acquire (or show proof of purchase) the required textbook by the 10th class day will result in the student being administratively dropped from the course. The University will assess financial obligations for the course to the student as with any other dropped class according to the fee schedule. In addition, your financial aid may be affected by the subsequent registration action(s).

If you are not financially able to purchase a required textbook for an engineering course prior to the 10th class day, you may apply to the College of Engineering Textbook Fund for a textbook voucher. The voucher can only be used at the Campus Bookstore. This voucher is a loan and must be paid back to the College of Engineering prior to the start of pre-registration for the coming semester. If the loan is not repaid, a hold will be placed on your account. Additional information and application materials can be obtained from the Assistant Dean's Office (SR Collins Room 349) and obtained online at the College of Engineering website under student resources. This policy is only for students who have declared a major (Engineering and Computer Science) in the Roy G. Perry College of Engineering.

Conduct:

1. Students will conduct themselves in a manner that is respectful to their fellow classmates.
2. Cell phones should be turned off or be put into silent mode during class time.
3. Cell phones or other electronic devices cannot be used during exams and tests. During exams, if you leave the examination room to go the restroom, you need to hand in your examination for grading. (Use restrooms before or after examinations.)
4. Students are NOT allowed to wear caps/hats in class.
5. Always bring essential tools: Textbook, paper, calculator.

End of Semester Course Assessment Report

This summary contains the following Information

1. Performance Statistics

- Total number of students in class
- The class average performance (**stated as %**) in each course outcome assessed in this class and the **two previous times course was assessed**.
- The acceptable class average for the class in each outcome area as set by your Department. **You cannot use any number of your choice**
- Percentage of students who scored below the expected average in each outcome.

2. Implementation Summary

- Brief summary of plans implemented during the semester based on last assessment report

3. Perceived Problems

- Instructor's **critical evaluation** of perceived problems that affected students' performance. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

5. Overall Trend over last three assessment periods

- Instructors summary of overall performance trend for each outcome measured over the last three periods.

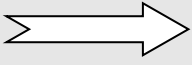
5. Were Expectations Met?

- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer NO.

**END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
ELEG 4307-P01 SERVOMECHANISMS AND CONTROL SYSTEMS
SPRING 2022 SEMESTER**

Report Prepared by: Musa

Report Date: MAY 17, 2022

Semester	Analysis Type	Number of Students	Outcome 2		
			An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.		
			Expected Class Average/	Class Average	% Students meeting Expected Average
Spring 2019	Direct	31	70	72	71%
Spring 2020	Direct	22	70	87	100%
Spring 2021	Direct	33	70	96	100%
Spring 2022	Direct	24	70	96.5	100%
Implementation Summary	Items implemented from previous report or after meeting previous instructor	Students develop an automated control system to regulate the depth of anesthesia. If the depth is low, the patient will feel greater pain and if the depth is high, the patient will die or become comatose. To measure the depth of anesthesia, the parameter used in general is Mean Arterial Pressure (MAP). The level of MAP serves as a guide for the delivery of anesthesia.			
Perceived Problems	Perceived problems are directly related to the PC and the sub items under them	Students were able to calculate the error of the control system, the steady state error when $T_d = 0$, the steady state output to step distribution ($R = 0$), to identify the step disturbance (surgical disturbance) of magnitude, D_0 affect the steady state output, and the sensitivity of closed loop transfer function to changes in "p", the MAP, ($T_d = 0$). This resulted in students writing reports with detailed description of the project design calculations.			
Plans for Addressing Problems	Plans for address specific measures to address PC and their sub areas	The following plans will be implemented the next time the course is taught: (a) Continue to help the student to learn how to produce accurate control system solutions. (b) emphasize to the students the importance of interoperation of the results.			
Overall Trend over Periods	Ascertain if there were improvements over previous semesters	Students were able do develop an automated control system to regulate the depth of anesthesia solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. Student's performance was above the expected average and above the previous semester's average.			
Were Expectations Met?		Yes			

**Grade Sheet Showing
Student and Class Performance in Outcomes
The computed semester average in each outcome
as stated in the Assessment report are
highlighted in boldface**

**Servomechanism and Control Systems -ELEG 4307-P01-
Electrical Engineering Major Spring 2022 (outcome 2) CRN: 26373**

Record	Student Name	ABET Outcome 2
1		99
2		100
3		100
4		100
5		99
6		99
7		95
8		100
9		99
10		100
11		95
12		100
13		100
14		99
15		100
16		100
17		80
18		95
19		100
20		80
21		80
22		97
23		100
24		100
Class Average		96.5

**OUTCOME SPECIFIC ASSIGNMENTS
USED TO ASSESS OUTCOMES**

ASSIGNMENTS FOR OUTCOME “2”

An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

**ELECTRICAL AND COMPUTER ENGINEERING
DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET ELEG
4307 SERVOMECHANICS AND CONTROL SYSTEMS
SPRING 2022**

Instructor: Sarhan M. Musa

Title of Assignment

Design Project

Outcome Measured Using this Assignment

Outcome 2

An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

Check the engineering design characteristics related to this assignment

X	Involves identifying the specific needs to be met by defining/understanding the problem and developing plans for the project to satisfy the need
X	Involves conducting a review of the literature and performing preliminary design by generating alternative ideas/solutions and applying creativity
X	Involves performing detailed engineering design leading to specification and fabrication/selection of components for system being designed.
	Involves consideration of one or more of the following (Please check those involved in this assignment.)
X	Public health
X	Safety and welfare
X	Global factors
X	Cultural factors
X	Social factors
X	Environmental factors
X	Economic factors
	Involves fabrication and testing of model or prototype

Brief justification of the suitability of assignment for the outcome

In this project, students develop an automated control system to regulate the depth of anesthesia. If the depth is low, the patient will feel greater pain and if the depth is high, the patient will die or become comatose. To measure the depth of anesthesia, the parameter used in general is Mean Arterial Pressure (MAP). The level of MAP serves as a guide for the delivery of anesthesia.

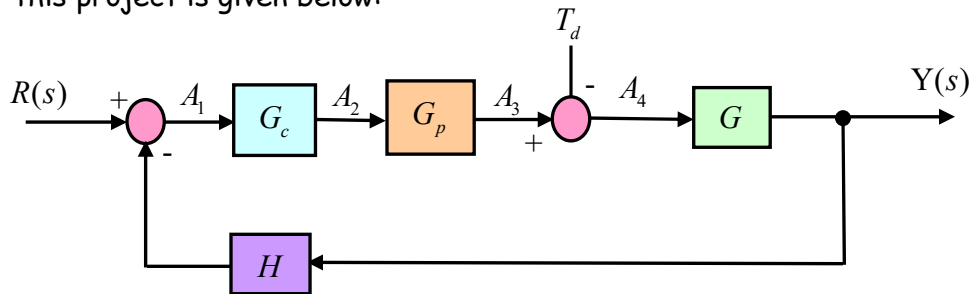


Electrical and Computer Engineering Department
Servomechanics and Control Systems/ ELEG 4307-P01
Project-Spring 2022

Last Name, , First.....

Blood Pressure Control during Anesthesia

The purpose of this project is to develop an automated system to regulate the depth of anesthesia. If the depth is low, the patient will feel greater pain and if the depth is high, the patient will die or become comatose. To measure the depth of anesthesia, the parameter used in general is Mean Arterial Pressure (MAP). The level of MAP serves as a guide for the delivery of anesthesia. The control system of this project is given below:



$R(s)$: Desired MAP; G_c : Valve; G_p : Pump; G : Patient; $Y(s)$: Actual MAP; H :

Sensor; T_d : Disturbance. Let $G_c(s) = \frac{1}{s} [k_D s^2 + k_p s + k_1]$, where k_D, k_p, k_1 are

controller gains. $G_p(s) = \frac{1}{s}$; $G(s) = \frac{1}{(s+p)^2}$; $H(s) = 1$; Step input, $R(s) = \frac{R_0}{s}$

; and Step disturbance, $T_d(s) = \frac{D_0}{s}$.

(1). Calculate the error of the control system $E(s)$.

(2). Calculate the steady state error when $T_d = 0$.

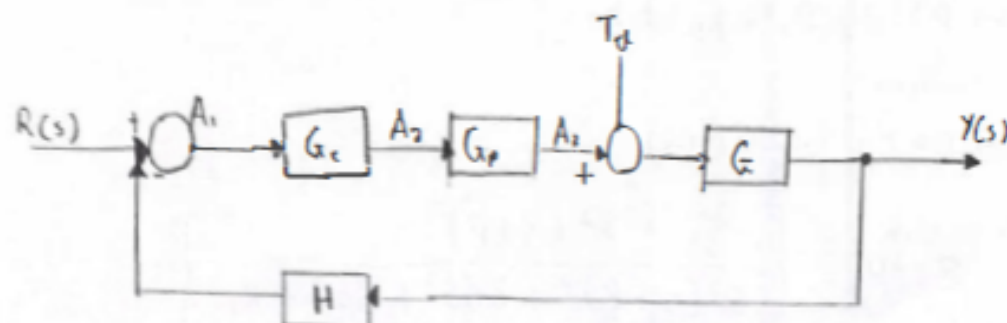
(3). Calculate the steady state output to step distribution ($R = 0$). Does the step disturbance (surgical disturbance) of magnitude, D_0 affect the steady state output?

(4). Calculate the sensitivity (S_p^T) of closed loop transfer function to changes in "p", the MAP, ($T_d = 0$).

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT
 Servomechanism and Control Systems / ELEG 4307-PO1
 Project - Spring 2022



$$G_e(s) = \frac{1}{s} [k_0 s^2 + k_p s + k_i]$$

$$G_p(s) = \frac{1}{s}, G(s) = \frac{1}{(s+p)^2}, H(s) = 1, R(s) = \frac{R_0}{s}, T_d(s) = \frac{D_0}{s}$$

$$\textcircled{1} E(s) = R(s) - H Y(s)$$

$$E(s) = R(s) - Y(s) \quad \text{--- (1)}$$

$$Y(s) = [E(s) G_e G_p - T_d] G$$

$$E(s) = R(s) - Y(s) = R(s) - (E(s) G_e G_p G - T_d G)$$

$$E(s) [1 + G_e G_p G] = R(s) + T_d G$$

$$E(s) = \frac{R(s)}{1 + G_e G_p G} + \frac{T_d G}{1 + G_e G_p G}$$

$$E(s) = \frac{R(s)}{1 + \frac{1}{s} [k_0 s^2 + k_p s + k_i] \times \frac{1}{s} \times \frac{1}{(s+p)^2}} + \frac{T_d \frac{1}{(s+p)^2}}{1 + \frac{1}{s} (k_0 s^2 + k_p s + k_i) \times \frac{1}{s} \times \frac{1}{(s+p)^2}}$$

$$E(s) = \frac{R(s) s^2 (s+p)^2}{s^2 (s+p)^2 + k_0 s^2 + k_p s + k_i} + \frac{T_d s^2}{s^2 (s+p)^2 + k_0 s^2 + k_p s + k_i}$$

② ess when $T_d = 0$, $R(s) = R_0/s$

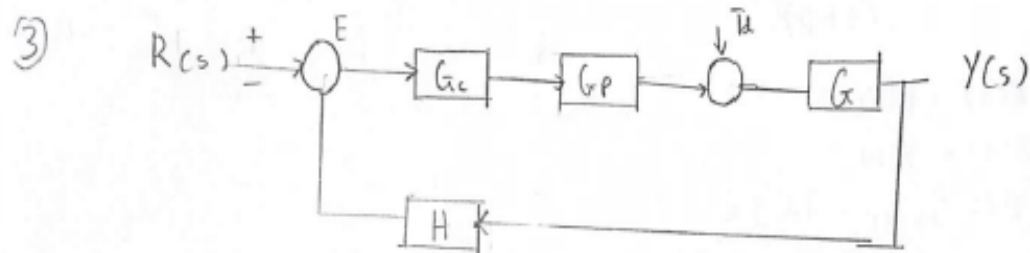
$$E(s) = \frac{R(s) s^2 (s+p)^2}{s^2 (s+p)^2 + K_D s^2 + K_P s + K_I}$$

By final value theorem:

$$e_{ss} = e(t \rightarrow \infty) = \lim_{s \rightarrow 0} s E(s)$$

$$e_{ss} = \lim_{s \rightarrow 0} s \left[\frac{\frac{R_0}{s} \times s^2 (s+p)^2}{s^2 (s+p)^2 + K_D s^2 + K_P s + K_I} \right]$$

$$= \frac{0^2 (p)^2}{0+0+0+K_I} = \boxed{0}$$



$$\Rightarrow Y(s) = [E G_c G_p - T_d] G_x$$

$$E = R - H Y$$

$$Y(s) = [(R - H Y) G_c G_p - T_d] G_x$$

$$Y(s) = \frac{R G_c G_p G_x}{1 + H G_c G_p G_x} - \frac{T_d G_x}{1 + H G_c G_p G_x} \quad (\text{closed loop eqn})$$

$$R = 1 \quad T_d = D_0/s$$

$$Y(s) = 0 - \frac{D_0}{s} \times \frac{1}{(s+p)^2}$$

$$1 + 1 \times \left(\frac{K_D s^2 + K_P s + K_I}{s} \right) \times \frac{1}{s} \times \frac{1}{(s+1)^2}$$

$$Y(s) = \frac{-D_0 s}{s^2 (s+p)^2 + K_D s^2 + K_P s + K_I}$$

$$\begin{aligned}
 Y_{ss} &= \lim_{s \rightarrow 0} sY(s) \\
 &= \lim_{s \rightarrow 0} s \times \frac{D \times s}{s^2(s+p)^2 + k_D s^2 + k_P s + k_I} \\
 &= \frac{0 \times 0}{0 + 0 + 0 + k_I} = 0
 \end{aligned}$$

D does not affect the steady state output

$$\begin{aligned}
 (4) \quad S_P^T &= \frac{P}{T} \frac{\partial T}{\partial P} \\
 T_d &= 0 \quad T(s) = \frac{Y(s)}{R(s)} \\
 T(s) &= \frac{Y(s)}{R(s)} = \frac{k_D s^2 + k_P s + k_I}{s^2(s+p)^2 + k_D s^2 + k_P s + k_I}
 \end{aligned}$$

$$\frac{\partial T(s)}{\partial P} = \left[\frac{[s^2(s+p)^2 + k_D s^2 + k_P s + k_I] \left(\frac{\partial k_D s^2 + k_P s + k_I}{\partial P} \right)}{(k_D s^2 + k_P s + k_I)^2} \right] - \left[\frac{(k_D s^2 + k_P s + k_I) \frac{\partial (s^2(s+p)^2 + k_D s^2 + k_P s + k_I)}{\partial P}}{(s^2(s+p)^2 + k_D s^2 + k_P s + k_I)^2} \right]$$

$$\frac{\partial T}{\partial P} = \frac{[0 - (k_D s^2 + k_P s + k_I) [s^2 \times 2(s+p) + \frac{\partial k_D s^2}{\partial P} + \frac{\partial k_P s}{\partial P} + \frac{\partial k_I}{\partial P}]]}{(s^2(s+p)^2 + k_D s^2 + k_P s + k_I)^2}$$

$\xrightarrow{\partial P} 0 \quad \xrightarrow{\partial P} 0 \quad \xrightarrow{\partial P} 0$

$$\frac{\partial T}{\partial P} = \frac{-(k_D s^2 + k_P s + k_I) \times 2(s+p) s^2}{(s^2(s+p)^2 + k_D s^2 + k_P s + k_I)^2}$$

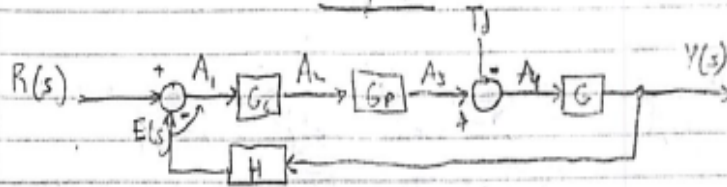
$$S_P^T = \frac{P}{T} \frac{\partial T}{\partial P} = \frac{P}{(k_D s^2 + k_P s + k_I)} \times \frac{-(k_D s^2 + k_P s + k_I) 2s^2(s+p)}{[s^2(s+p)^2 + k_D s^2 + k_P s + k_I]}$$

$$\boxed{S_P^T = \frac{-2s^2 P (s+p)}{s^2(s+p)^2 + k_D s^2 + k_P s + k_I}} \quad \text{Ans}$$

AVERAGE

95

Project



$R(s)$: Desired MAP; G_c : Valve; G_p : Pump; G : Patient; $Y(s)$:

Actual MAP; H : Sensor; T_d : Disturbance.

Let $G_c(s) = \frac{1}{s} [K_D s^2 + K_P s + K_I]$, where K_D, K_P, K_I are controller gains.

$G_p(s) = \frac{1}{s}$; $G(s) = \frac{1}{(s+p)}$; $H(s) = 1$; Step input, $R(s) = \frac{R_0}{s}$

and Step disturbance, $T_d(s) = \frac{D_0}{s}$.

1) Error of control system $E(s)$.

$$G(s) = G_c(s) \cdot G_p(s) \quad G(s) = \frac{K_D s^2 + K_P s + K_I}{s^2 (s+p)^2}$$

$$E_1(s) = \frac{R(s)}{1 + G(s)H(s)} = \frac{R_0 s (s+p)^2}{s^2 (s+p)^2 + K_D s^2 + K_P s + K_I}$$

$$\frac{R_0 (s^3 + 2s^2 p + s p^2)}{s^2 (s^2 + 2s p + p^2) + K_D s^2 + K_P s + K_I} = \frac{R_0 (s^3 + 2s^2 p + s p^2)}{s^4 + 2s^3 p + (K_D + p^2) s^2 + K_P s + K_I}$$

$$G = \frac{1}{(s+p)^2} \quad G_c G_p H = \frac{K_D s^2 + K_P s + K_I}{s} \times \frac{1}{s} = \frac{K_D s^2 + K_P s + K_I}{s^2}$$

$$E_2(s) = \frac{T_d(s)}{1 + G(s)H(s)} = \frac{\frac{D_0}{s}}{1 + \frac{K_D s^2 + K_P s + K_I}{s} \left(\frac{1}{(s+p)^2} \right)}$$

$$E(s) = E_1(s) + E_2(s) = \frac{(R_0 + D_0) (s^3 + 2s^2 p + s p^2)}{s^4 + 2s^3 p + (K_D + p^2) s^2 + K_P s + K_I}$$

When $T_d = 0$

$$2) \frac{R(s)}{1 + G(s)H(s)} = \frac{R_0(s^3 + 2s^2p + 3p^2)}{s^4 + 2s^3p + (K_D + p^2)s^2 + K_Ps + K_I}$$

Steady State Error: $e_{ss} = \lim_{s \rightarrow 0} \frac{R_0 s^2 (s+p)^2}{s^2 (s+p)^2 + K_D s^2 + K_P s + K_I} = 0$

$(e_{ss} = 0)$

3) when $R=0$ $G(s) = \frac{1}{(s+p)^2}$

$H(s) = G_c(s) G_p(s) H(s) = \frac{K_D s^2 + K_P s + K_I}{s^2}$

$$\frac{1}{(s+p)^2} = \frac{s^2}{s^2 (s+p)^2 + K_D s^2 + K_P s + K_I}$$

Steady state output $= \lim_{s \rightarrow 0} \rightarrow = 0 =$

Steady state output is 0 for both $R=0$ & $I_d=0$
the step disturbance (surge) of D_0 does
affect the steady state output

-5

4) sensitivity (S_p^T)

$$G(s) = G_c(s) G_p(s) \quad G = \frac{K_p s^2 + K_p s + K_i}{s^2 (s+p)^2} \quad H(s) = 1$$

$$T = \frac{G(s)}{1 + G(s)H(s)} = \frac{K_p s^2 + K_p s + K_i}{s^2 (s+p)^2 + K_p s^2 + K_p s + K_i}$$

$$(S_p^T) \quad \frac{\partial T}{\partial P} \approx \frac{P}{T} = \frac{-(K_p s^2 + K_p s + K_i) 2s^2 (p+s) \times \frac{P}{T}}{[s^2 (s+p)^2 + K_p s^2 + K_p s + K_i]^2}$$

$$\frac{P(s^2 (s+p)^2 + K_p s^2 + K_p s + K_i)}{(K_p s^2 + K_p s + K_i)}$$

$$S_p^T = \frac{2s^2 P(p+s)}{s^2 (s+p)^2 + K_p s^2 + K_p s + K_i} = \boxed{\frac{2s^2 P^2 + 2s^3 P}{s^4 + 2s^3 p + (K_p + p^2)s^2 + K_p s + K_i}}$$

BELOW AVERAGE

1.

Project 1

80

$$A_1 G_c = A_2$$

$$A_2 G_p = A_3$$

$$A_3 - T_d = A_4$$

$$A_4 G_1 = y(s)$$

$$y(s) = \{ [A_1 G_c] G_p - T_d \} G_1$$

$$- y(s) = [G_p R(s) G_c - H(s) y(s) G_c G_p - T_d] G_1$$

$$- y(s) = G G_c G_p R(s) - G G_c G_p H(s) y(s) - T_d G_1$$

$$- y(s) [1 + G G_c G_p] = G G_c G_p R(s) - T_d G_1$$

$$y(s) = \frac{G G_c G_p R(s) - T_d G_1}{1 + G G_c G_p} \quad (\text{equation 1})$$

$$\sim e(s) = A_1 = R(s) - H(s) y(s) \Rightarrow e(s) = R(s) -$$

$$\left[\frac{G G_c G_p R(s) H(s) + T_d G H(s)}{1 + G G_c G_p} \right]$$

$$\left[G G_c G_p R(s) H(s) \right]$$

$$- e(s) = R(s) + G G_c G_p R(s) - G G_c G_p R(s) H(s) + T_d G H(s)$$

$$- e(s) = R(s) [1 + G G_c G_p - G G_c G_p H(s)] + T_d G H(s)$$

$$H(s) = 1 \text{ given}$$

$$- e(s) = R(s) [1 + G G_c G_p - G G_c G_p] + T_d G H(s)$$

$$\boxed{e(s) = R(s) + T_d G} \quad \text{--- 10 ---} \quad H(s) = 1$$

2.

$$e_{ss} = \lim_{s \rightarrow 0} S e(s) = \lim_{s \rightarrow 0} [S R(s) + T_d G]$$

given ($T_d = 0$)

$$= e_{ss} = \lim_{s \rightarrow 0} S R(s) = 0$$

3.

$$Y(s) = \frac{G G_c G_P R(s) - T_d G}{1 + G G_c G_P} \quad R = 0$$

$$Y(s) = \frac{-T_d G}{1 + G G_c G_P}$$

Steady state output:

$$y_{ss} = \lim_{s \rightarrow 0} s Y(s) = \lim_{s \rightarrow 0} s \frac{-T_d G}{1 + G G_c G_P}$$

$$\frac{s x - T_d G}{1 + G G_c G_P}$$

$$= \lim_{s \rightarrow 0}$$

$$s x - \frac{D_0}{s} \times \frac{1}{(s+p)^2}$$

$$\frac{1 + R_D s^2 + K_P s + K_I}{s^2 (s+p)^2}$$

Answer:

$$y_{ss} = \frac{-D_0}{p^2 + K_I}$$

$$y_{ss} = \lim_{s \rightarrow 0} \frac{-D_0}{(s+p)^2}$$

$$\frac{(s+p)^2 + K_D s^2 + K_P s + K_I}{(s+p)^2}$$

yes, steady state output is affected.

$\lim_{t \rightarrow \infty} y(t) = 0$ @ $s=0$

$$= \lim_{s \rightarrow 0} \frac{-D_0}{(s+p)^2 + K_D s^2 + K_P s + K_I}$$

4.

$$y(s) = \frac{G G_c G_p R(s) - T_d G}{1 + G G_c G_p}$$

$$y(s) + G G_c G_p y(s) = G G_c G_p R(s) - T_d G$$

$$\frac{2y(s)}{2G} + G G_c G_p \frac{2y(s)}{2G} + G_c G_p y(s) =$$

$$G_c G_p R(s) - 0$$

(other terms are constant)

$$\sim \frac{2y(s)}{2G} [1 + G G_c G_p] = G_c G_p [R(s) - y(s)]$$

$$\sim \frac{2y(s)}{2G} = \frac{G_c G_p (R(s) - y(s))}{1 + G G_c G_p} \quad \text{where } G = \frac{1}{(s+p)^2}$$

$$\frac{2G}{2P} = \frac{(s+p)^2 \cdot 0 - 1(s+p) \times 2}{(s+p)^4}$$

$$\sim \frac{2G}{2P} = \frac{-2}{(s+p)^3}$$

$$\frac{2y(s)}{2G} \times \frac{2G}{2P} = \frac{2y(s)}{2P} = \frac{G G_p [R(s) - y(s)]}{1 + G G_c G_p}$$

$$\times \frac{-2}{(s+p)^3}$$

U. continued

$$\frac{2y(s)}{2P} = \frac{2G_c G_P [y(s) - R(s)]}{(1 + G_c G_P)(s+P)^3}$$

$$S_P^T = \frac{2y(s)}{y(s)} \times \frac{P}{2P} = \frac{2y(s)}{2P} \times \frac{P}{y(s)}$$

$$= \frac{2G_c G_P [y(s) - R(s)]}{(1 + G_c G_P)(s+P)^3} \times \frac{P(1 + G_c G_P)}{G_c G_P R(s)} \quad [T_d = 0]$$

$$S_P^T = \frac{2P[y(s) - R(s)]}{(s+P)^3 \cdot G_P R(s)}$$

$$= \frac{2P[y(s) - R(s)]}{(s+P)^3 \cdot \frac{1}{(s+P)^2} R(s)} = \frac{2P[y(s) - R(s)]}{(s+P) R(s)}$$

$$= \frac{2P}{s+P} \left[\frac{y(s)}{R(s)} - 1 \right] = \frac{2P}{s+P} \left[\frac{G_c G_P}{1 + G_c G_P} - 1 \right]$$

$$= \frac{2P}{s+P} \left[\frac{G_c G_P - 1 - G_c G_P}{1 + G_c G_P} \right] = S_P^T = \frac{2P}{s+P} \left[\frac{-1}{1 + G_c G_P} \right]$$

$$G_c G_P = \frac{k_P s^2 + k_P s + k_I}{s^2 (s+P)^2}$$

4 continued

$$S^T_P = \frac{2P}{(S+P)} \times \frac{-1}{\frac{1+kDs^2+kPs+kI}{s^2(s+P)^2}}$$

$$= \frac{2P}{(S+P)} \times \frac{-s^2(s+P)^2}{s^2(s+P)^2 + kDs^2 + kPs + kI}$$

$$= \frac{-2Ps^2(s+P)}{s^4 + 2Ps^3 + Ps^2 + kDs^2 + kPs + kI}$$

$$S^T_P = \frac{-2Ps^2(s+P)}{s^4 + sPs^3 + (kD+P)s^2 + kPs + kI}$$

ASSIGNMENT #1

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Assignment 1-Spring 2022

Last Name,....., First.....

Select a single answer choice:

1. Control system is a study
 - (a) To control the failure of a system
 - (b) To control the operation of a function
 - (c) To control the actual output to match with desired output
 - (d) To control the input

2. Open loop control system is the one that
 - (a) Depend on output
 - (b) Depend on input
 - (c) Does not depend on input
 - (d) Does not depend on output

3. Closed loop control system is the one that
 - (a) Depend on output
 - (b) Provides feedback
 - (c) Provides stability
 - (d) All of the above

4. Positive feedback system
 - (a) Makes the system unstable
 - (b) Makes the system stable
 - (c) Makes the output positive
 - (d) None of the above

5. Controller is defined as
 - (a) A device that activates the plant
 - (b) A device that activates the actuator
 - (c) A device that controls the sensor
 - (d) All of the above

6. Actuator is defined as
 - (a) A device that activates the plant
 - (b) A device that activates the controller
 - (c) A device that activates the sensor
 - (d) All of the above

7. A Plant or Process is defined as

- (a) A system that controls the activator
- (b) A system that controls the sensor
- (c) A system that activates the controller
- (d) A system to be controlled

8. A sensor is defined as

- (a) A device to measure the output from plant
- (b) A device to give feedback to controller
- (c) A device to function as sensing element in the system
- (d) All of the above

9. Transfer function is defined as

- (a) Ratio of input to output
- (b) Ratio of output to input
- (c) Sum of output and input
- (d) Difference between output and input

10. $G/(1+GH)$ is the transfer function for

- (a) Open loop system
- (b) Positive feedback system
- (c) Negative feedback system
- (d) None of the above

11. $G/(1-GH)$ is the transfer function for

- (a) Open loop system
- (b) Positive feedback system
- (c) Negative feedback system
- (d) None of the above

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

100

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01

Assignment 1-Spring 2022

Last Name, [REDACTED] First [REDACTED]

Select a single answer choice:

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- (a) To control the failure of a system
- (b) To control the operation of a function
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- (b) ☒ Positive feedback system
- (c) Negative feedback system
- (d) None of the above

AVERAGE

82

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01

Assignment 1-Spring 2022

Last Name, _____, First _____

Select a single answer choice:

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- (a) Open loop system
 - (b) Positive feedback system
 - (c) Negative feedback system
 - (d) None of the above

BELOW AVERAGE

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01

Assignment 1-Spring 2022

Last Name: First:

Select a single answer choice:

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- (d) Difference between output and input

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- (c) Negative feedback system
- (d) None of the above

11. $G/(1-GH)$ is the transfer function for

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- (b) Positive feedback system
- (c) Negative feedback system
- (d) None of the above

ASSIGNMENT #2

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Assignment 2-Spring 2022

Last Name,....., First.....

Select a single answer choice on this sheet:

1. If G_1 and G_2 are in series, the equivalent transfer function is equal to
 - (a) G_1/G_2
 - (b) G_1+G_2
 - (c) G_1-G_2
 - (d) G_1*G_2

2. When you move the summing point from behind to ahead, the input 'R2' becomes
 - (a) R_2+G
 - (b) R_2/G
 - (c) R_2-G
 - (d) R_2*G

3. When you move the Pick-off point from ahead to behind, the Pick-off value is
 - (a) Divided by G
 - (b) Multiplied by G
 - (c) All of the above
 - (d) None of the above

4. In SFG (signal flow Graph), the Nodes represent
 - (a) Input
 - (b) Output
 - (c) Junction point in a path
 - (d) All of the above

5. In SFG (signal flow Graph), the lines (Branches) represent
 - (a) The total transfer function
 - (b) The summing point
 - (c) The loop transfer function
 - (d) The path of transfer function

6. The path transfer function is equal to
- (a) Sum of all transfer function in a path
 - (b) Ratio of all transfer function in a path
 - (c) Product of all transfer function in a path
 - (d) None of the above

7. Mason's formula is a function of
- (a) Path transfer function
 - (b) Loop transfer function
 - (c) Determinant function
 - (d) All of the above

8. For single path,
- (a) $\Delta_1 = 1$
 - (b) All the loop touches the path
 - (c) $T(s) = P_1 \Delta_1 / \Delta$
 - (d) All of the above

9. For two paths,
- (a) $T(s) = (P_1 + P_2) (\Delta_1 + \Delta_2) / \Delta$
 - (b) $T(s) = (P_1 \Delta_1 + P_2 \Delta_2) / \Delta$
 - (c) $T(s) = (P_1 - P_2) (\Delta_1 - \Delta_2) / \Delta$
 - (d) $T(s) = (P_1 \Delta_1 * P_2 \Delta_2) / \Delta$

10. The loops are identified as touching, if
- (a) They are adjacent
 - (b) They across
 - (c) They overlap
 - (d) All of the above

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

60

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Assignment 2-Spring 2022

Last Name: [REDACTED]

Id: [REDACTED]

Select a single answer choice on this sheet:

1. If G_1 and G_2 are in series, the equivalent transfer function is equal to

- (a) G_1/G_2
- (b) G_1+G_2
- (c) G_1-G_2
- (d) $G_1 \cdot G_2$

2. When you move the summing point from behind to ahead, the input 'R2' becomes

- (a) R_2+G
- (b) R_2/G
- (c) R_2-G
- (d) $R_2 \cdot G$

3. When you move the Pick-off point from ahead to behind, the Pick-off value is

- (a) Divided by G
- (b) Multiplied by G
- (c) All of the above
- (d) None of the above

4. In SFG (signal flow Graph), the Nodes represent

- (a) Input
- (b) Output
- (c) Junction point in a path
- (d) All of the above

5. In SFG (signal flow Graph), the lines (Branches) represent

- (a) The total transfer function
- (b) The summing point
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- (d) None of the above

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- (b) Loop transfer function
- (c) Determinant function
- (d) All of the above

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- (b) All the loop touches the path
- (c) $T(s) = P_1 \Delta_1 / \Delta$
- (d) All of the above

9. For two paths,

- (a) $T(s) = (P_1 + P_2) (\Delta_1 + \Delta_2) / \Delta$
- (b) $T(s) = (P_1 \Delta_1 + P_2 \Delta_2) / \Delta$
- (c) $T(s) = (P_1 - P_2) (\Delta_1 - \Delta_2) / \Delta$
- (d) $T(s) = (P_1 \Delta_1 * P_2 \Delta_2) / \Delta$

10. The loops are identified as touching, if

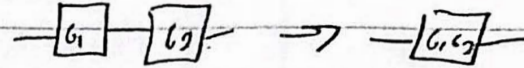
- (a) They are adjacent
- (b) They across
- (c) They overlap
- (d) All of the above

AVERAGE

Assignment #2

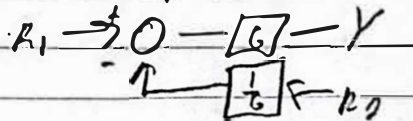
- 1.) If G_1 and G_2 are in series, the equivalent transfer function is equal to:

D.) $G_1 \times G_2$



- 2.) When you move the summing point from behind to ahead, the input ' R_2 ' becomes:

B.) R_2/G



- 3.) When you move the pick-off point from ahead to behind, the pick-off value is:

A.) Divided by G

- 4.) In SFG (signal flow graph), the Nodes represent:

D.) All of the above

(Input, Output, & Junction point in a path)

- 5.) In SFG (signal flow graph), the lines (Branches) represent

D.) The path of transfer function

- 6.) The path transfer function is equal to:

A.) Sum of all transfer function in a path

- 7.) Mason's formula is a function of:

D.) All of the above (Path, Loop, and Determinant function)

- 8.) For single path:

A.) $D_1 = 1$

- 9.) For two paths:

B.) $T(s) = (P_1 D_1 + P_2 D_2) / D$

- 10.) The loops are identified as touching, if:

D.) All of the above (Adjacent, across, overlap)

BELOW AVERAGE

70

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Assignment 2-Spring 2022

Last Name, [REDACTED], First, [REDACTED]

Select a single answer choice on this sheet:

1. If G_1 and G_2 are in series, the equivalent transfer function is equal to
- (a) G_1/G_2
 - (b) G_1+G_2
 - (c) G_1-G_2
 - (d) G_1*G_2

2. When you move the summing point from behind to ahead, the input 'R2' becomes
- (a) R_2+G
 - (b) R_2/G
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 - (d) R_2*G

3. When you move the Pick-off point from ahead to behind, the Pick-off value is
- (a) Divided by G
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 - (d) None of the above

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- (a) Path transfer function
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- (d) All of the above

8. For single path,

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- (c) $T(s) = P_1 \Delta_1 / \Delta$
- (d) All of the above

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- (b) $T(s) = (P_1 \Delta_1 + P_2 \Delta_2) / \Delta$
- (c) $T(s) = (P_1 - P_2) (\Delta_1 - \Delta_2) / \Delta$
- (d) $T(s) = (P_1 \Delta_1 * P_2 \Delta_2) / \Delta$

10. The loops are identified as touching, if

- (a) They are adjacent
- (b) They across
- (c) They overlap
- (d) All of the above

ASSIGNMENT #3

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Assignment 3-Spring 2022

Last Name,....., First.....

Select a single answer choice on this sheet:

1. The error is given as
 - (a) $E = R - Y$
 - (b) $E = R (1-T)$
 - (c) $E = R - R (Y/R)$
 - (d) All of the above
2. To minimize the disturbance, the controller should have,
 - (a) Large gain at high frequencies
 - (b) Small gain at high frequencies
 - (c) Large gain at low frequencies
 - (d) Small gain at low frequencies
3. To minimize the noise, the controller should have,
 - (a) Small gain at high frequencies
 - (b) Small gain at low frequencies
 - (c) Large gain at low frequencies
 - (d) Large gain at high frequencies
4. Sensitivity of a system transfer function (T) with respect to Plant transfer function (G) is given by
 - (a) $S_G^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$
 - (b) $S_G^T = \left(\frac{\partial T}{\partial G} \right) / \left(\frac{T}{G} \right)$
 - (c) $S_T^G = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$
 - (d) None of the above
5. Sensitivity of T(s) with respect to a parameter (α) in G(s) is given by
 - (a) $S_\alpha^T = \left(\frac{\partial T / T}{\partial \alpha / \alpha} \right)$
 - (b) $S_\alpha^T = S_G^T S_\alpha^G$
 - (c) $S_\alpha^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{G}{T} \right) \left(\frac{\partial G}{\partial \alpha} \right) \left(\frac{\alpha}{G} \right)$
 - (d) All of the above

6. The steady state error is the value of error function, $e(t)$ evaluated at

- (a) $t = 0$
- (b) $t = \infty$
- (c) $s = \infty$
- (d) All of the above

7. Gain setting is defined as

- (a) The effect of change in gain on error function
- (b) The effect of change in gain on steady state error
- (c) The effect of error on gain
- (d) The effect of gain on sensitivity

8. If $E(s) = \frac{(s+4)(s+5)}{s(s^2+3s+2)}$; the steady state error is,

- (a) 10
- (b) 0
- (c) 0.1
- (d) ∞

9. If $E(s) = \left(\frac{1}{s^3}\right) \frac{(s^3+2s^2)}{(s^3+4s^2+5s+1)}$; the steady state error is,

- (a) 0.5
- (b) ∞
- (c) 0
- (d) 2

10. If $E(s) = \frac{s^2+3s+4}{s^3+4s^2+(5+2K)s}$ and the steady state error, $e_{ss} = 0.05$,

the value of "K" is,

- (a) 375
- (b) 3.75
- (c) 37.5
- (d) 0.375

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

100

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-PO1

Assignment 3-Spring 2022

Last Name, _____, First _____

Select a single answer choice on this sheet:

1. The error is given as

- (a) $E = R - Y$
(b) $E = R(1-T)$
(c) $E = R - R(Y/R)$
(d) All of the above

2. To minimize the disturbance, the controller should have,

- (a) Large gain at high frequencies
(b) Small gain at high frequencies
(c) Large gain at low frequencies
(d) Small gain at low frequencies

3. To minimize the noise, the controller should have,

- (a) Small gain at high frequencies
(b) Small gain at low frequencies
(c) Large gain at low frequencies
(d) Large gain at high frequencies

4. Sensitivity of a system transfer function (T) with respect to Plant transfer function (G) is given by

(a) $S_G^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$

(b) $S_G^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$

(c) $S_G^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$

(d) None of the above

$$S_G^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$$

$$S_G^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$$

means same thing

5. Sensitivity of $T(s)$ with respect to a parameter (α) in $G(s)$ is given by

(a) $S_\alpha^T = \left(\frac{\partial T}{\partial \alpha} \right) \left(\frac{T}{\alpha} \right)$

(b) $S_\alpha^T = S_G^T S_\alpha^G$

(c) $S_\alpha^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right) \left(\frac{\partial G}{\partial \alpha} \right) \left(\frac{\alpha}{G} \right)$

(d) All of the above

6. The steady state error is the value of error function, $e(t)$ evaluated at

- (a) $t = 0$
- (b) $t = \infty$
- (c) $s = \infty$
- (d) All of the above

7. Gain setting is defined as

- (a) The effect of change in gain on error function
- (b) The effect of change in gain on steady state error
- (c) The effect of error on gain
- (d) The effect of gain on sensitivity

8. If $E(s) = \frac{(s+4)(s+5)}{s(s^2+3s+2)}$; the steady state error is,

$$\lim_{s \rightarrow 0} sE(s) = \frac{(0+4)(0+5)}{0^2+3(0)+2} = \frac{20}{2} = 10$$

- (a) 10
- (b) 0
- (c) 0.1
- (d) ∞

9. If $E(s) = \left(\frac{1}{s^3} \right) \frac{(s^3+2s^2)}{(s^3+4s^2+5s+1)}$; the steady state error is,

$$\lim_{s \rightarrow 0} \left(\frac{1}{s^2} \frac{(s^3+2s^2)}{s^3+4s^2+5s+1} \right) = 2$$

- (a) 0.5
- (b) ∞
- (c) 0
- (d) 2

10. If $E(s) = \frac{s^2+3s+4}{s^3+4s^2+(5+2K)s}$ and the steady state error, $e_{ss} = 0.05$,

the value of "K" is,

$$0.05 = \lim_{s \rightarrow 0} \frac{s^2+3s+4}{s^2+4s+(5+2K)}$$

$$K = \frac{75}{2} = 37.5$$

- (a) 375
- (b) 3.75
- (c) 37.5
- (d) 0.375

Can't find this term in my notes or in the text book.

AVERAGE

80

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01

Assignment 3-Spring 2022

Last Name, _____, First _____

Select a single answer choice on this sheet:

1. The error is given as

(a) $E = R - Y$

(b) $E = R(1-T)$

(c) $E = R - R(Y/R)$

(d) All of the above

2. To minimize the disturbance, the controller should have,

(a) Large gain at high frequencies

(b) Small gain at high frequencies

(c) Large gain at low frequencies

(d) Small gain at low frequencies

3. To minimize the noise, the controller should have,

(a) Small gain at high frequencies

(b) Small gain at low frequencies

(c) Large gain at low frequencies

(d) Large gain at high frequencies

4. Sensitivity of a system transfer function (T) with respect to Plant transfer function (G) is given by

(a) $S_G^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$

(b) $S_G^T = \left(\frac{\partial T}{\partial G} \right) / \left(\frac{T}{G} \right)$

(c) $S_T^G = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$

(d) None of the above

5. Sensitivity of T(s) with respect to a parameter (α) in G(s) is given by

(a) $S_\alpha^T = \left(\frac{\partial T/T}{\partial \alpha/\alpha} \right) = \frac{\partial T}{T} \cdot \frac{\alpha}{\partial \alpha} = \frac{\partial T}{\partial \alpha} \cdot \frac{\alpha}{T}$

(b) $S_\alpha^T = S_G^T S_\alpha^G$

(c) $S_\alpha^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{G}{T} \right) \left(\frac{\partial G}{\partial \alpha} \right) \left(\frac{\alpha}{G} \right)$

(d) All of the above

6. The steady state error is the value of error function, $e(t)$ evaluated at

- (a) $t = 0$
- (b) $t = \infty$ ✓
- (c) $s = \infty$
- (d) All of the above

7. Gain setting is defined as

- (a) The effect of change in gain on error function
- (b) The effect of change in gain on steady state error ✓
- (c) The effect of error on gain
- (d) The effect of gain on sensitivity

8. If $E(s) = \frac{(s+4)(s+5)}{s(s^2+3s+2)}$; the steady state error is,

- (a) 10 ✓
- (b) 0
- (c) 0.1
- (d) ∞

$$\lim_{s \rightarrow 0} s \cdot E(s) = s \cdot \frac{(s+4)(s+5)}{s(s^2+3s+2)}$$

$$= \frac{4 \cdot 5}{0+0+2} = \frac{20}{2} = 10$$

9. If $E(s) = \left(\frac{1}{s^3}\right) \frac{(s^3+2s^2)}{(s^3+4s^2+5s+1)}$; the steady state error is,

- (a) 0.5
- (b) ∞
- (c) 0
- (d) 2 ✓

$$\lim_{s \rightarrow 0} s \cdot E(s) = s \cdot \frac{1}{s^3} \cdot \frac{s^2 \cdot (s+2)}{s^3+4s^2+5s+1}$$

$$= \frac{0+2}{0+0+0+1} = 2$$

10. If $E(s) = \frac{s^2+3s+4}{s^3+4s^2+(5+2K)s}$ and the steady state error, $e_{ss} = 0.05$,

the value of "K" is,

- (a) 375
- (b) 3.75
- (c) 37.5 ✓
- (d) 0.375

$$\lim_{s \rightarrow 0} [E(s) \cdot s] = 0.05$$

$$s \cdot \frac{s^2+3s+4}{s^3+4s^2+(5+2K)s} = 0.05$$

$$\frac{0+3 \cdot 0+4}{0+0+5+2K} = 0.05$$

$$4 = 0.25 + 0.1K$$

$$\Rightarrow K = \frac{4-0.25}{0.1} = 37.5$$

BELOW AVERAGE

70

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01

Assignment 3-Spring 2022

Last Name, [REDACTED], First [REDACTED]

Select a single answer choice on this sheet:

1. The error is given as

- (a) $E = R - Y$
(b) $E = R(1-T)$
(c) $E = R - R(Y/R)$
(d) All of the above

2. To minimize the disturbance, the controller should have,

- (a) Large gain at high frequencies
(b) Small gain at high frequencies
(c) Large gain at low frequencies
(d) Small gain at low frequencies

3. To minimize the noise, the controller should have,

- (a) Small gain at high frequencies
(b) Small gain at low frequencies
(c) Large gain at low frequencies
(d) Large gain at high frequencies

4. Sensitivity of a system transfer function (T) with respect to Plant transfer function (G) is given by

- (a) $S_G^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$
(b) $S_G^T = \left(\frac{\partial T}{\partial G} \right) / \left(\frac{T}{G} \right) = \left(\frac{\partial T}{\partial G} \right) \left(\frac{G}{T} \right)$
(c) $S_T^G = \left(\frac{\partial T}{\partial G} \right) \left(\frac{T}{G} \right)$
(d) None of the above

5. Sensitivity of T(s) with respect to a parameter (α) in G(s) is given by

- (a) $S_\alpha^T = \left(\frac{\partial T / T}{\partial \alpha / \alpha} \right)$
(b) $S_\alpha^T = S_G^T S_\alpha^G$
(c) $S_\alpha^T = \left(\frac{\partial T}{\partial G} \right) \left(\frac{G}{T} \right) \left(\frac{\partial G}{\partial \alpha} \right) \left(\frac{\alpha}{G} \right)$
(d) All of the above

6. The steady state error is the value of error function, $e(t)$ evaluated

B.

at

(a) $t = 0$

(b) $t = \infty$

(c) $s = \infty$

(d) All of the above

7. Gain setting is defined as

(a) The effect of change in gain on error function

(b) The effect of change in gain on steady state error

(c) The effect of error on gain

(d) The effect of gain on sensitivity

8. If $E(s) = \frac{(s+4)(s+5)}{s(s^2+3s+2)}$; the steady state error is,

A

(a) 10

(b) 0

(c) 0.1

(d) ∞

$$\lim_{s \rightarrow 0} s E(s) = s(Es) = s \cdot \left(\frac{(s+4)(s+5)}{s(s^2+3s+2)} \right)$$

$$= \lim_{s \rightarrow 0} \frac{(s+4)(s+5)}{s^2+3s+2} = \frac{20}{2} = 10$$

9. If $E(s) = \left(\frac{1}{s^3} \right) \frac{(s^3+2s^2)}{(s^3+4s^2+5s+1)}$; the steady state error is,

D

(a) 0.5

(b) ∞

(c) 0

(d) 2

$$\text{Error} = \lim_{s \rightarrow 0} s E(s) = s \cdot \frac{s^3+2s^2}{s^3(s^3+4s^2+5s+1)}$$

$$= s \cdot \frac{s^2(s+2)}{s^3(s^3+4s^2+5s+1)} = \frac{2}{1} = 2$$

10. If $E(s) = \frac{s^2+3s+4}{s^3+4s^2+(5+2K)s}$ and the steady state error, $e_{ss} = 0.05$,

the value of "K" is, when $s = 0$

C

(a) 375

(b) 3.75

(c) 37.5

(d) 0.375

$$0.05 = \frac{4}{5+2K}$$

$$0.25 + 0.1K = 4$$

$$0.1K = 3.75$$

$$K = 37.5$$

ASSIGNMENT #4

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Assignment 4-Spring 2022

Last Name,....., First.....

Select a single answer choice on this sheet:

1. $T = \frac{9s}{s^2 + 10s}$ represents

- (a) First order system
- (b) Second order system
- (c) Third order system
- (d) All of the above

2. Final value theorem is useful to find,

- (a) Steady state error
- (b) Steady state response
- (c) The final value of output
- (d) All of the above

3. If $E(s) = \frac{8s^2 + 5s}{9s^3 + 4s^2}$, the steady state error is

- (a) 8/9
- (b) 9/8
- (c) 5/4
- (d) 4/5

4. If $T_s = t_s = \frac{K}{\zeta\omega_n}$ the value of K for settling time within 2% of final value is

- (a) 4.6
- (b) 3.9
- (c) 3.0
- (d) 2.3

5. For the above problem, the value of K for settling time within 5% of final value is,

- (a) 4.6
- (b) 3.9
- (c) 3.0
- (d) 2.3

6. For ramp input the steady state error is zero for

- (a) Type-0 system
- (b) Type-1 system
- (c) Type-2 system
- (d) All of the above

7. For step input, the steady state error is NOT zero and for

- (a) Type-0 system
- (b) Type-1 system
- (c) Type-2 system
- (d) All of the above

8. For quadratic (Parabola) input, the steady state error, $e_{ss} = \frac{A}{k_a}$ for

- (a) Type-0 system
- (b) Type-1 system
- (c) Type-2 system
- (d) All of the above

9. The error function is defined for

- (a) $E(s) = R(s) - Y(s)$
- (b) $E(s) = R(s)[1 - T(s)]$
- (c) $E(s) = -R(s) \left[\frac{Y(s) - R(s)}{R(s)} \right]$
- (d) All of the above

10. If percent overshoot and settling time are given, we can find

- (a) Damping ratio
- (b) Natural frequency
- (c) Peak time and Peak value
- (d) All of the above

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01

Assignment 4-Spring 2022

Last Name, _____, First, _____

Select a single answer choice on this sheet:

1. $T = \frac{9s}{s^2 + 10s}$ represents $= \frac{\cancel{s}(9)}{\cancel{s}(s+10)} = \frac{9}{s+10}$

- (a) First order system
(b) Second order system
(c) Third order system
(d) All of the above

2. Final value theorem is useful to find,

- (a) Steady state error
(b) Steady state response
(c) The final value of output
(d) All of the above

3. If $E(s) = \frac{8s^2 + 5s}{9s^3 + 4s^2}$, the steady state error is

- (a) 8/9
(b) 9/8
(c) 5/4
(d) 4/5

$$e_{ss} = \lim_{s \rightarrow 0} \left(\frac{1}{s} \left(\frac{s(8s+5)}{s^2(9s+4)} \right) \right)$$

$$e_{ss} = \lim_{s \rightarrow 0} \left(\frac{8s+5}{9s+4} \right) = \frac{5}{4}$$

4. If $T_s = t_s = \frac{K}{\zeta \omega_n}$ the value of K for settling time within 2% of final value is

- (a) 4.6
(b) 3.9
(c) 3.0
(d) 2.3

$$\frac{5}{f\omega_n} \Rightarrow 1\%$$

$$4 < K < 5$$

$$\frac{4}{f\omega_n} \Rightarrow 2\%$$

5. For the above problem, the value of K for settling time within 5% of final value is,

- (a) 4.6
(b) 3.9
(c) 3.0
(d) 2.3

$$3 < K < 4$$

not equal to

6. For ramp input the steady state error is zero for

(a) Type-0 system

(b) Type-1 system

(c) Type-2 system

(d) All of the above

$$N > 1 \quad e_{ss} = 0$$

7. For step input, the steady state error is NOT zero and for

(a) Type-0 system

(b) Type-1 system

(c) Type-2 system

(d) All of the above

$$N \geq 1 \quad e_{ss} = 0$$

$$N < 1 \quad e_{ss} \neq 0$$

8. For quadratic (Parabola) input, the steady state error, $e_{ss} = \frac{A}{k_a}$ for

(a) Type-0 system

(b) Type-1 system

(c) Type-2 system

(d) All of the above

9. The error function is defined for

(a) $E(s) = R(s) - Y(s)$

(b) $E(s) = R(s)[1 - T(s)]$

(c) $E(s) = -R(s) \left[\frac{Y(s) - R(s)}{R(s)} \right]$

(d) All of the above

10. If percent overshoot and settling time are given, we can find

(a) Damping ratio ✓

(b) Natural frequency ✓

(c) Peak time and Peak value ✓

(d) All of the above

$$mPO = e^{-\left(\frac{\zeta \pi}{\beta}\right)} \cdot 100\%$$

$$\beta = \sqrt{1 - \zeta^2}$$

$$t_s = \frac{4}{\zeta \omega_n} \quad t_s = \frac{\#}{\zeta \omega_n}$$

$$t_p = \frac{\pi}{\omega_n \sqrt{1 - \zeta^2}}$$

AVERAGE

80

**Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELE6 4307-P01**

Assignment 4-Spring 2022

Last Name, _____, First _____

Select a single answer choice on this sheet:

1. $T = \frac{9s}{s^2 + 10s}$ represents

(A.)

- (a) First order system
(b) Second order system
(c) Third order system
(d) All of the above

$$\frac{9s}{s^2 + 10s} = \frac{9}{s+10} \cdot \frac{k}{s+1}$$

2. Final value theorem is useful to find,

(D.)

- (a) Steady state error
(b) Steady state response
(c) The final value of output
(d) All of the above

3. If $E(s) = \frac{8s^2 + 5s}{9s^3 + 4s^2}$, the steady state error is

(C.)

- (a) 8/9
(b) 9/8
(c) 5/4
(d) 4/5

$$E(s) = \lim_{s \rightarrow 0} s \cdot \frac{8s^2 + 5s}{9s^3 + 4s^2} = \frac{8(0) + 5}{9(0) + 4} = \frac{5}{4}$$

4. If $T_s = t_s = \frac{K}{\zeta \omega_n}$ the value of K for settling time within 2% of final value is

(B.)

- (a) 4.6
(b) 3.9
(c) 3.0
(d) 2.3

$$T_s = t_s = \frac{4}{\zeta \omega_n}$$

$$K \approx 3.9$$

5. For the above problem, the value of K for settling time within 5% of final value is,

(C.)

- (a) 4.6
(b) 3.9
(c) 3.0
(d) 2.3

$$K \approx 3$$

6. For ramp input the steady state error is zero for

- (a) Type-0 system
- (b) Type-1 system
- (c) Type-2 system
- (d) All of the above

X (A.)

7. For step input, the steady state error is NOT zero and for

- (a) Type-0 system
- (b) Type-1 system
- (c) Type-2 system
- (d) All of the above

X (B.)

8. For quadratic (Parabola) input, the steady state error, $e_{ss} = \frac{A}{k_a}$ for

- (a) Type-0 system
- (b) Type-1 system
- (c) Type-2 system
- (d) All of the above

✓ (C.)

9. The error function is defined for

- (a) $E(s) = R(s) - Y(s)$
- (b) $E(s) = R(s)[1 - T(s)]$
- (c) $E(s) = -R(s) \left[\frac{Y(s) - R(s)}{R(s)} \right]$
- (d) All of the above

✓ (D.)

10. If percent overshoot and settling time are given, we can find

- (a) Damping ratio
- (b) Natural frequency
- (c) Peak time and Peak value
- (d) All of the above

✓ (D.)

BELOW AVERAGE

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01

Assignment 4-Spring 2022

Last Name, [REDACTED], First, [REDACTED]

Select a single answer choice on this sheet:

1. $T = \frac{9s}{s^2 + 10s}$ represents

(a) First order system

(b) Second order system

(c) Third order system

(d) All of the above

2. Final value theorem is useful to find,

(a) Steady state error

(b) Steady state response

(c) The final value of output

(d) All of the above

3. If $E(s) = \frac{8s^2 + 5s}{9s^3 + 4s^2}$, the steady state error is

(a) 8/9

(b) 9/8

(c) 5/4

(d) 4/5

4. If $T = \frac{K}{s^2 + \zeta\omega_n s}$ the value of K for settling time within 2% of final value is

(a) 4.6

(b) 3.9

(c) 3.0

(d) 2.3

5. For the above problem, the value of K for settling time within 5% of final value is,

(a) 4.6

(b) 3.9

(c) 3.0

(d) 2.3

6. For ramp input the steady state error is zero for

- (a) Type-0 system
- (b) Type-1 system
- (c) Type-2 system
- (d) All of the above

7. For step input, the steady state error is NOT zero and for

- (a) Type-0 system
- (b) Type-1 system
- (c) Type-2 system
- (d) All of the above

8. For quadratic (Parabola) input, the steady state error, $e_{ss} = \frac{A}{k}$ for

- (a) Type-0 system
- (b) Type-1 system
- (c) Type-2 system
- (d) All of the above

9. The error function is defined for

- (a) $E(s) = R(s) - Y(s)$
- (b) $E(s) = R(s)[1 - T(s)]$
- (c) $E(s) = -R(s) \left[\frac{Y(s) - R(s)}{R(s)} \right]$
- (d) All of the above

10. If percent overshoot and settling time are given, we can find

- (a) Damping ratio
- (b) Natural frequency
- (c) Peak time and Peak value
- (d) All of the above

ASSIGNMENT #5

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Assignment 5-Spring 2022

Last Name....., First.....

**Select a single answer choice on this assignment:*

- 1. The characteristic equation is,**
 - (a) The number of controller transfer function
 - (b) The denominator of controller transfer function
 - (c) The numerator of total (system) transfer function
 - (d) The denominator of total (system) transfer function

- 2. The roots of characteristic equation are called as**
 - (a) Zeros
 - (b) Poles
 - (c) Complex zeros
 - (d) None of the above

- 3. For stability, the roots of characteristic equation should be on,**
 - (a) Left half plane of S-Plot
 - (b) Right half plane of S-Plot
 - (c) On the Real Axis of S-Plot
 - (d) On the vertical Axis of S-Plot

- 4. For stability, the coefficients of "s" in the characteristic equation should be**
 - (a) All positive
 - (b) All negative
 - (c) At least one positive and one negative
 - (d) Equal number of positive and negative

- 5. For stability, the Routh array should be**
 - (a) All values in the first (leftmost) column be positive
 - (b) All values in the second column be positive
 - (c) At least one negative value in the first column
 - (d) None of the above

- 6. Regarding first two rows on Routh array,**
 - (a) One row is with odd powers and the other with even powers
 - (b) The coefficients of "s" are used to complete these two rows
 - (c) First row begins with highest power of characteristic equation
 - (d) All of the above

7. On the given Routh array, the value "b1" is,

s^3	1	8	0
s^2	2	4	0
s^1	b_1	b_2	
s^0	c_1		

- (a) -12
- (b) 6
- (c) 0
- (d) 3

8. The value of "c1" on the Routh array is,

s^3	1	8	0
s^2	2	4	0
s^1	b_1	b_2	
s^0	c_1		

- (a) 4
- (b) 0
- (c) 8
- (d) -16

9. Auxiliary polynomial is used for stability if

- (a) One of the elements on the first column of Routh array is zero
- (b) One of the columns on the Routh array is zero
- (c) One of the rows on the Routh array has all zero
- (d) One of the elements on the first row of Routh array is zero

10. Auxiliary polynomial,

- (a) Is the row preceding the row of zeros.
- (b) Is an even order polynomial.
- (c) Has symmetric roots
- (d) All of the above

11. If the roots are on vertical axis, the system is

- (a) Stable
- (b) Unstable
- (c) Marginally stable
- (d) None of the above

12. A marginally stable system in general considered as,

- (a) Stable system
- (b) Unstable system
- (c) Neutral system
- (d) None of the above

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

600

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01

Assignment 5-Spring 2022

Last Name....., First.....

**Select a single answer choice on this assignment:*

1. The characteristic equation is,
(a) The number of controller transfer function
(b) The denominator of controller transfer function
(c) The numerator of total (system) transfer function
(d) The denominator of total (system) transfer function
2. The roots of characteristic equation are called as
(a) Zeros
(b) Poles
(c) Complex zeros
(d) None of the above
3. For stability, the roots of characteristic equation should be on,
(a) Left half plane of S-Plot
(b) Right half plane of S-Plot
(c) On the Real Axis of S-Plot
(d) On the vertical Axis of S-Plot
4. For stability, the coefficients of "s" in the characteristic equation should be
(a) All positive
(b) All negative
(c) At least one positive and one negative
(d) Equal number of positive and negative
5. For stability, the Routh array should be
(a) All values in the first (leftmost) column be positive
(b) All values in the second column be positive
(c) At least one negative value in the first column
(d) None of the above
6. Regarding first two rows on Routh array,
(a) One row is with odd powers and the other with even powers
(b) The coefficients of "s" are used to complete these two rows
(c) First row begins with highest power of characteristic equation
(d) All of the above

7. On the given Routh array, the value "b1" is,

s^3	1	8	0
s^2	2	4	0
s^1	b_1	b_2	
s^0	c_1		

$$b_1 = -\frac{\begin{vmatrix} 1 & 8 \\ 2 & 4 \end{vmatrix}}{2} = \frac{16 - 4}{2} = \frac{12}{2} = 6$$

- (a) -12
 (b) 6
 (c) 0
 (d) 3

8. The value of "c1" on the Routh array is,

s^3	1	8	0
s^2	2	4	0
s^1	6	0	
s^0	c_1		

$$b_2 = 0$$

$$c_1 = 4$$

- (a) 4
 (b) 0
 (c) 8
 (d) -16

9. Auxiliary polynomial is used for stability if

- (a) One of the elements on the first column of Routh array is zero
 (b) One of the columns on the Routh array is zero
 (c) One of the rows on the Routh array has all zero
 (d) One of the elements on the first row of Routh array is zero

10. Auxiliary polynomial,

- (a) Is the row preceding the row of zeros.
 (b) Is an even order polynomial.
 (c) Has symmetric roots
 (d) All of the above

11. If the roots are on vertical axis, the system is

- (a) Stable
 (b) Unstable
 (c) Marginally stable
 (d) None of the above

12. A marginally stable system in general considered as,

- (a) Stable system
 (b) Unstable system
 (c) Neutral system
 (d) None of the above

AVERAGE

84

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01

Assignment 5-Spring 2022

Last Name....., First.....

**Select a single answer choice on this assignment:*

1. The characteristic equation is,

- (a) The number of controller transfer function
- ☒ (b) The denominator of controller transfer function
- (c) The numerator of total (system) transfer function
- (d) The denominator of total (system) transfer function

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- (a) Zeros
- ☒ (b) Poles
- (c) Complex zeros
- (d) None of the above

3. For stability, the roots of characteristic equation should be on,

- ☒ (a) Left half plane of S-Plot
- (b) Right half plane of S-Plot
- (c) On the Real Axis of S-Plot
- (d) On the vertical Axis of S-Plot

4. For stability, the coefficients of "s" in the characteristic equation should be

- ☒ (a) All positive
- (b) All negative
- (c) At least one positive and one negative
- (d) Equal number of positive and negative

5. For stability, the Routh array should be

- ☒ (a) All values in the first (leftmost) column be positive
- (b) All values in the second column be positive
- (c) At least one negative value in the first column
- (d) None of the above

6. Regarding first two rows on Routh array,

- (a) One row is with odd powers and the other with even powers
- (b) The coefficients of "s" are used to complete these two rows
- (c) First row begins with highest power of characteristic equation
- ☒ (d) All of the above

7. On the given Routh array, the value "b1" is,

s^3	1	8	0
s^2	2	4	0
s^1	b_1	b_2	
s^0	c_1		

- (a) -12
☒ (b) 6
 (c) 0
 (d) 3

8. The value of "c1" on the Routh array is,

s^3	1	8	0
s^2	2	4	0
s^1	b_1	b_2	
s^0	c_1		

- (a) 4
 (b) 0
☒ (c) 8
 (d) -16

9. Auxiliary polynomial is used for stability if

- (a) One of the elements on the first column of Routh array is zero
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☒ (c) One of the rows on the Routh array has all zero
 (d) One of the elements on the first row of Routh array is zero

10. Auxiliary polynomial,

- (a) Is the row preceding the row of zeros.
 (b) Is an even order polynomial.
 (c) Has symmetric roots
☒ (d) All of the above

11. If the roots are on vertical axis, the system is

- (a) Stable
 (b) Unstable
☒ (c) Marginally stable
 (d) None of the above

12. A marginally stable system in general considered as,

- (a) Stable system
 (b) Unstable system
☒ (c) Neutral system
 (d) None of the above

BELOW AVERAGE

76

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01

Assignment 5-Spring 2022

Last Name....., First.....

**Select a single answer choice on this assignment:*

1. The characteristic equation is,

- (a) The number of controller transfer function
- (b) The denominator of controller transfer function
- ☒ (c) The numerator of total (system) transfer function
- (d) The denominator of total (system) transfer function

2. The roots of characteristic equation are called as

- (a) Zeros
- ☒ (b) Poles
- (c) Complex zeros
- (d) None of the above

3. For stability, the roots of characteristic equation should be on,

- ☒ (a) Left half plane of S-Plot
- (b) Right half plane of S-Plot
- (c) On the Real Axis of S-Plot
- (d) On the vertical Axis of S-Plot

4. For stability, the coefficients of "s" in the characteristic equation should be

- ☒ (a) All positive
- (b) All negative
- (c) At least one positive and one negative
- (d) Equal number of positive and negative

5. For stability, the Routh array should be

- ☒ (a) All values in the first (leftmost) column be positive
- (b) All values in the second column be positive
- (c) At least one negative value in the first column
- (d) None of the above

6. Regarding first two rows on Routh array,

- (a) One row is with odd powers and the other with even powers
- (b) The coefficients of "s" are used to complete these two rows
- (c) First row begins with highest power of characteristic equation
- ☒ (d) All of the above

7. On the given Routh array, the value "b1" is,

s^3	1	8	0
s^2	2	4	0
s^1	b_1	b_2	
s^0	c_1		

- (a) -12
(b) 6
(c) 0
(d) 3

8. The value of "c1" on the Routh array is,

s^3	1	8	0
s^2	2	4	0
s^1	b_1	b_2	
s^0	c_1		

- (a) 4
(b) 0
(c) 8
(d) -16

9. Auxiliary polynomial is used for stability if

- (a) One of the elements on the first column of Routh array is zero
(b) One of the columns on the Routh array is zero
(c) One of the rows on the Routh array has all zero
(d) One of the elements on the first row of Routh array is zero

10. Auxiliary polynomial,

- (a) Is the row preceding the row of zeros.
(b) Is an even order polynomial.
(c) Has symmetric roots
(d) All of the above

11. If the roots are on vertical axis, the system is

- (a) Stable
(b) Unstable
(c) Marginally stable
(d) None of the above

12. A marginally stable system in general considered as,

- (a) Stable system
(b) Unstable system
(c) Neutral system
(d) None of the above

ASSIGNMENT #6

Electrical and Computer Engineering Department
Servomechanics and Control Systems/ ELEG 4307-P01
Assignment 6-Spring 2022

Last Name....., First.....

Consider a second-order system:

$$G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

With undamped natural frequency $\omega_n = 5$ rad/sec and damping ratio $\zeta = 0.4$.

- 1. Generate MATLAB code for getting the second-order system $G(s)$.**
- 2. Generate MATLAB code which will yield a plot of the unit-step response of this system.**
- 3. Generate MATLAB code which will yield a plot of the unit-step response of this system labeling the x axis as "t Sec" and the y axis as "Output".**

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

Electrical and Computer Engineering Department
Servomechanism and Control Systems/ ELEG 4307-P01
Assignment 6-Spring 2022

Last Name: [REDACTED], First: [REDACTED]

Consider a second-order system:

$$G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

With undamped natural frequency $\omega_n = 5$ rad/sec and damping ratio $\zeta = 0.4$.

1. Generate MATLAB code for getting the second order system $G(s)$.

```
Editor - C:\School Stuff\ELEG 4307 (Servo & Cntrl Sys)
assignment6_1.m
1      wn=5;
2      dam=0.4;
3      n=[wn^2];
4      d=[1 2*wn*dam wn^2];
5      G=tf(n,d);
```

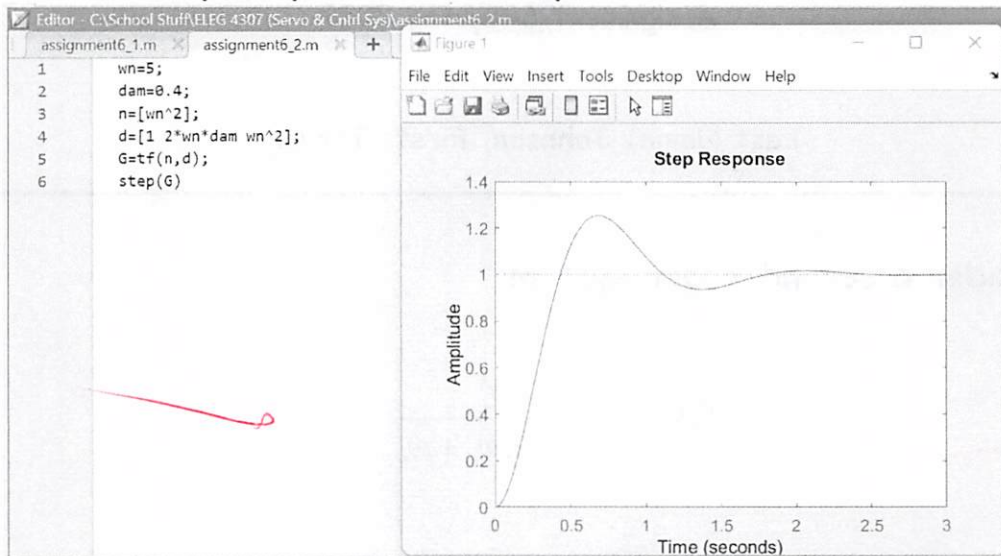
Obtained value of G

$G =$

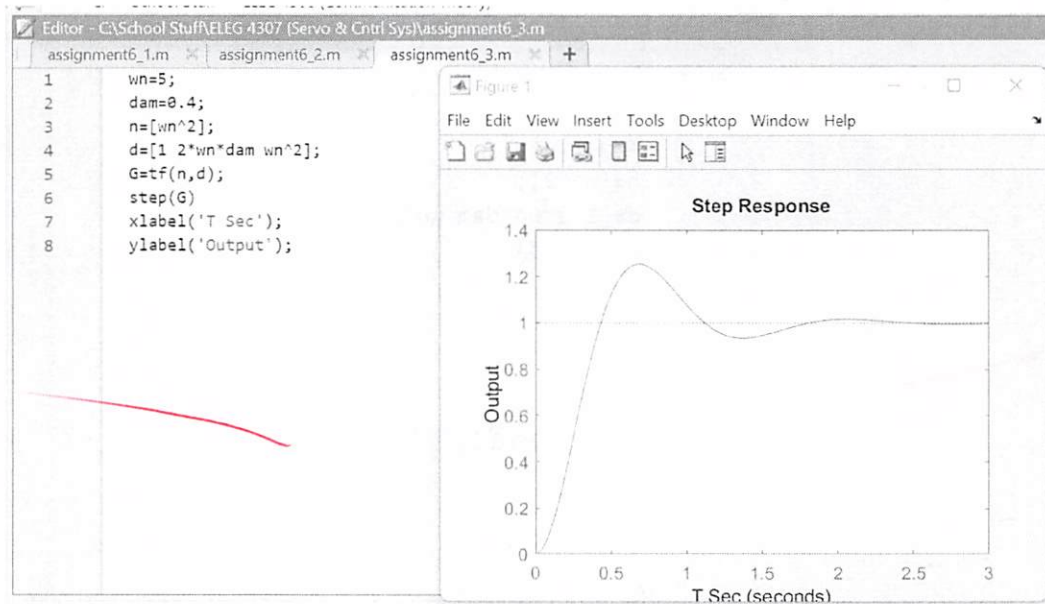
25

 $s^2 + 4s + 25$

2. Generate MATLAB code which will yield a plot of the unit-step response of this system.



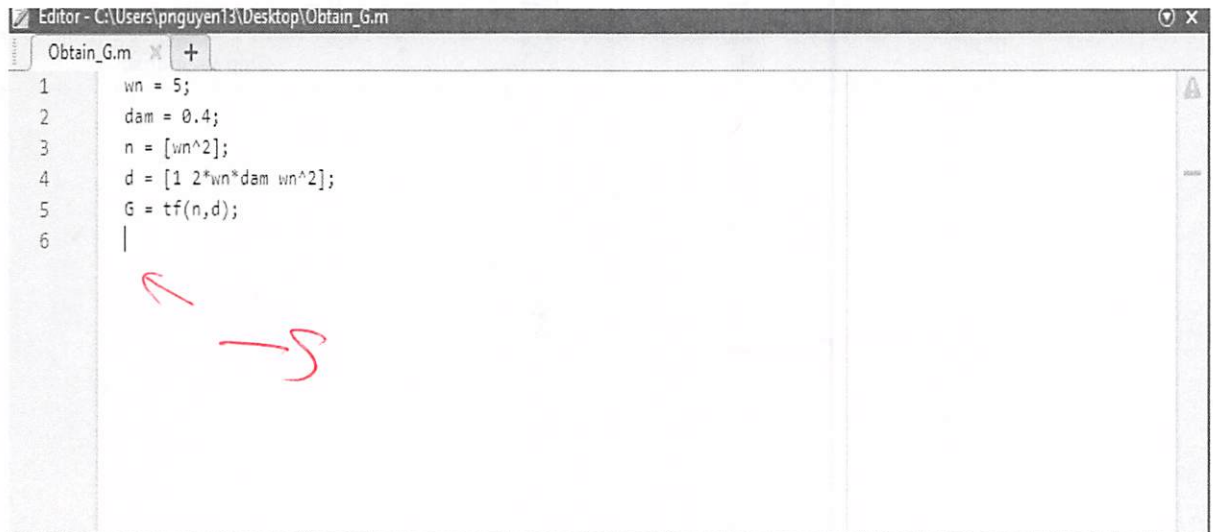
3. Generate MATLAB code which will yield a plot of the unit-step response of this system labeling the x axis as "t Sec" and the y axis as "Output".



AVERAGE

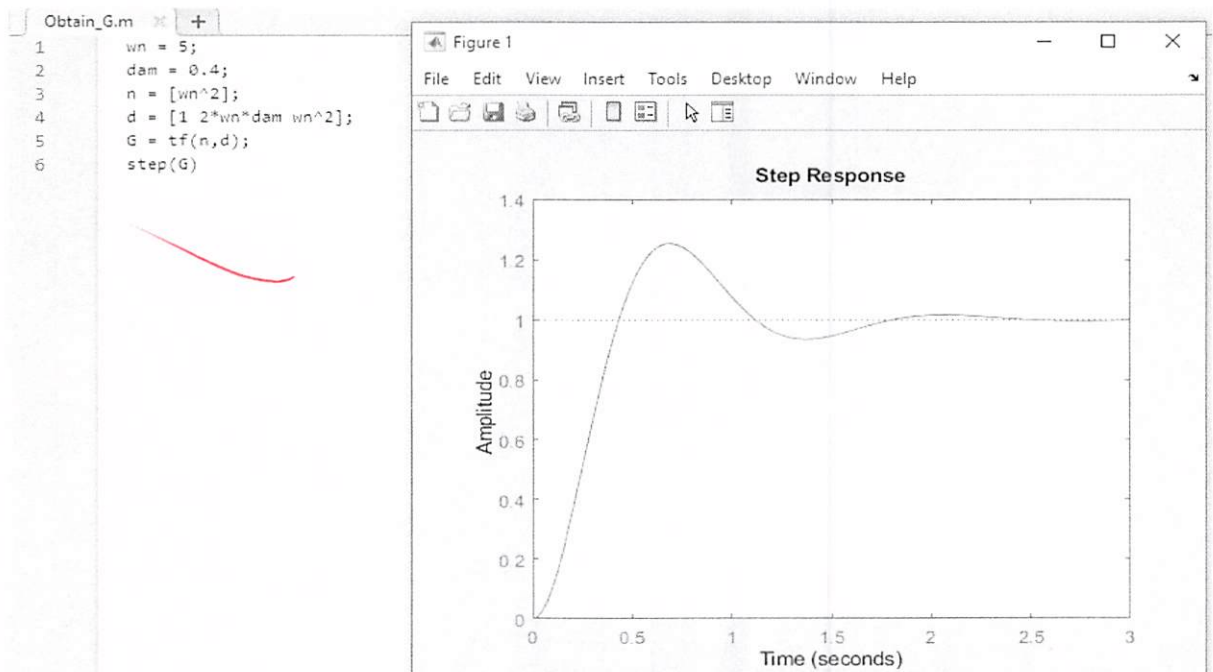
Assignment 6

1. Generate MATLAB to obtain $G(s)$

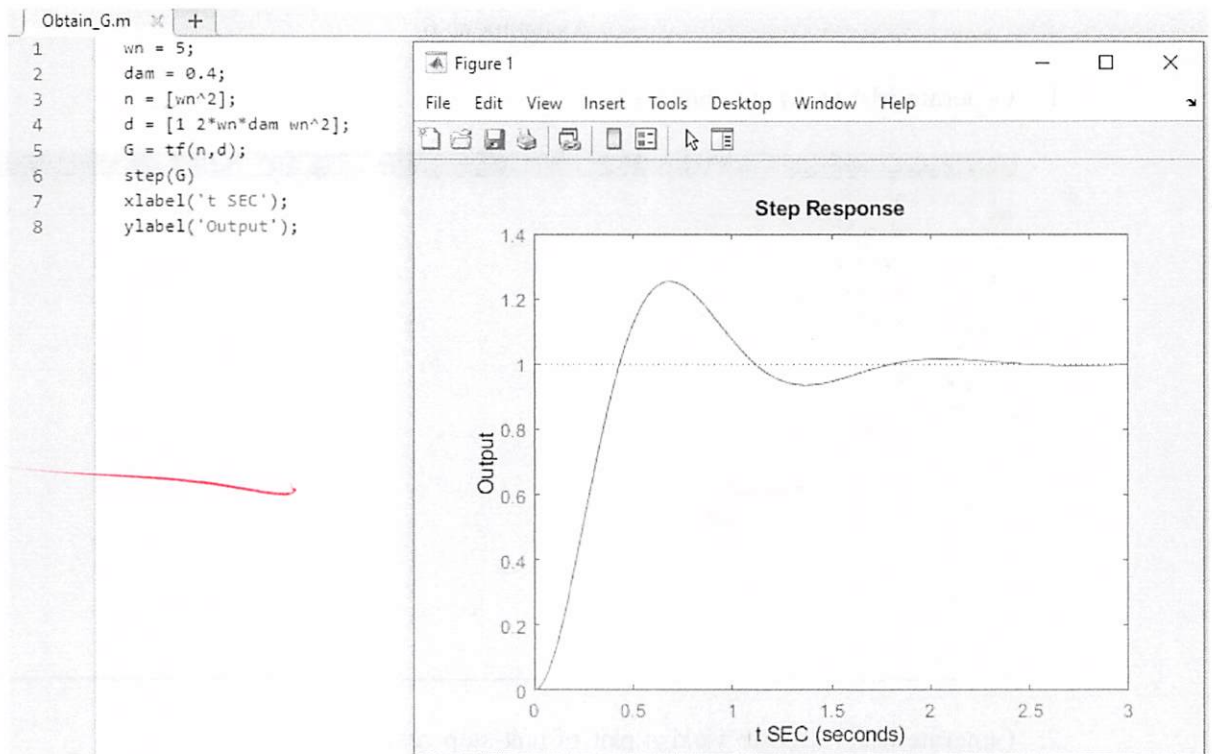


```
1 wn = 5;  
2 dam = 0.4;  
3 n = [wn^2];  
4 d = [1 2*wn*dam wn^2];  
5 G = tf(n,d);  
6
```

2. Generate MATLAB to yield a plot of unit-step response



3. Generate MATLAB code which will yield a plot of the unit-step response as “t Sec” and y-axis as “Output”



BELOW AVERAGE

80

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Assignment 6-Spring 2022

Last Name.....
First.....

1)

Clc
 Clear all
 Close all

Syms s

t=(0:0.01:3) ' ;

wn=5; % natural frequency in rad/sec

zeta=0.4; % Damping ratio =0.4

%-----

Gs=tf ((0 0 wn. ^2), [1 (2*zeta*wn) 9wn.^2])) % Generating transfer function for
 % second order system

%-----

Step (Gs) % Plotting the unit step response

Grid

Figure

%-----

[y,t] = step(Gs);

Plot (t,y,'r')

Xlabel (' t(sec)') ; % Label x-axis as t(sec)

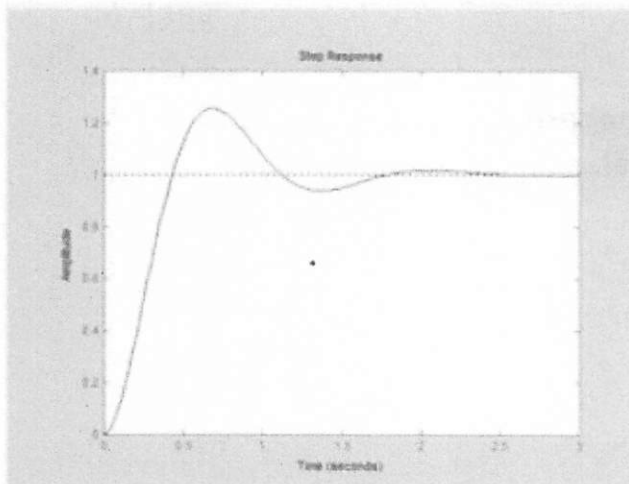
Ylabel (' Output') ; %Label y axis as Output

Title (' Step response')

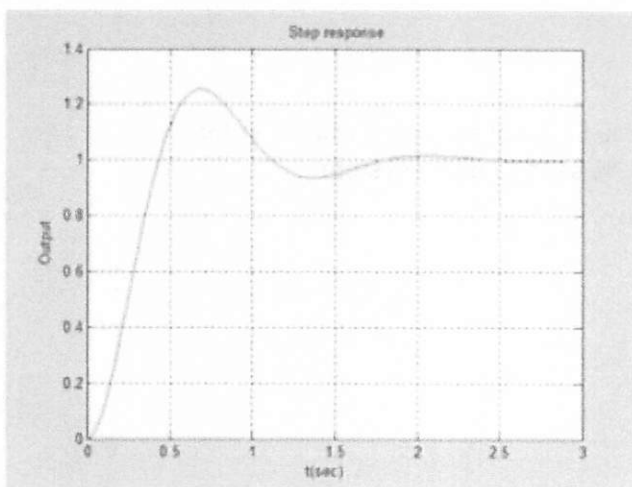
Grid

72 - 20

2)



3)



ASSIGNMENT #7

Electrical and Computer Engineering Department
Servomechanicsm and Control Systems/ ELEG 4307-P01
Assignment 7-Spring 2022

Consider a unity-feedback control system with the following feedforward transfer function:

$$G(s) = \frac{K}{(s^2 + 2s + 2)(s^2 + 2s + 5)}$$

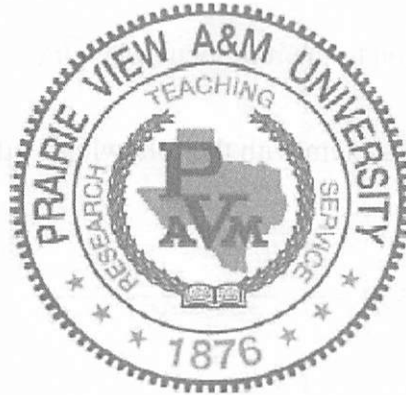
Using MATLAB, write the code and plot the root loci and their asymptotes.

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

PRAIRIE VIEW A&M UNIVERSITY

ROY G. PERRY COLLEGE OF ENGINEERING



Course Number: ELEG 4307

Servomechanism and Control Systems

Course Topic: Assignment 7

Submitted by:

[REDACTED]

Date of Submission: 4/25/22

Instructor: Dr. Sarhan Musa

Introduction

In this experiment we will be simulating and plotting root loci and asymptotes with MATLAB.

Asymptote originates from the center of gravity or centroid and goes to infinity at definite some angle. Asymptotes provide direction to the root locus when they depart break away points.

Consider a unity-feedback control system with the following feedforward transfer function:

$$G(s) = \frac{K}{(s^2 + 2s + 2)(s^2 + 2s + 5)}$$

The feedforward transfer function $G(s)$ can be written as

$$G(s) = \frac{K}{s^4 + 4s^3 + 11s^2 + 14s + 10}$$

Note that as s approaches infinity, $\lim_{s \rightarrow \infty} G(s)$ can be written as

$$\begin{aligned}\lim_{s \rightarrow \infty} G(s) &= \lim_{s \rightarrow \infty} \frac{K}{s^4 + 4s^3 + 11s^2 + 14s + 10} \\ &= \lim_{s \rightarrow \infty} \frac{K}{s^4 + 4s^3 + 6s^2 + 4s + 1} \\ &= \lim_{s \rightarrow \infty} \frac{K}{(s + 1)^4}\end{aligned}$$

where we used the following formula:

$$(s + a)^4 = s^4 + 4as^3 + 6a^2s^2 + 4a^3s + a^4$$

The expression

$$\lim_{s \rightarrow \infty} G(s) = \lim_{s \rightarrow \infty} \frac{K}{(s + 1)^4}$$

gives the equation for the asymptotes.

The MATLAB program to plot the root loci of $G(s)$ and the asymptotes is given in MATLAB Program below. Note that the numerator and denominator for $G(s)$ are

num

```
num = [1]
den = [1 4 11 14 10]
```

For the numerator and denominator of the asymptotes $\lim_{s \rightarrow \infty} G(s)$ we used

```
numa = [1]
dena = [1 4 6 4 1]
```

Since the characteristic equation for the system is

$$(s^2 + 2s + 2)(s^2 + 2s + 5) + K = 0$$

MATLAB Program

```
% ***** Root-locus plot *****
num = [1];
den = [1 4 11 14 10];
numa = [1];
dena = [1 4 6 4 1];
r = rlocus(num,den);
plot(r,'-')
hold
Current plot held
plot(r,'o')
rlocus(numa,dena);
v = [-6 4 -5 5]; axis(v); axis('square')
grid
title('Plot of Root Loci and Asymptotes')
```

Figure 1: MATLAB Code

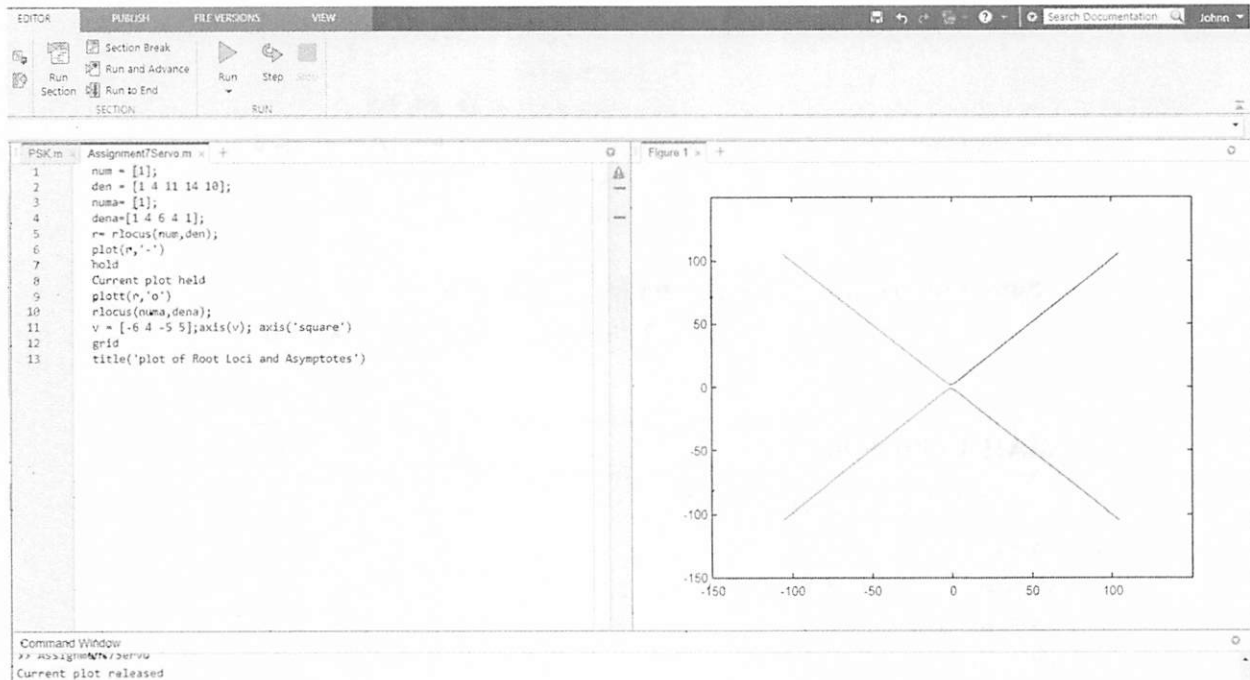


Figure 2: Simulation

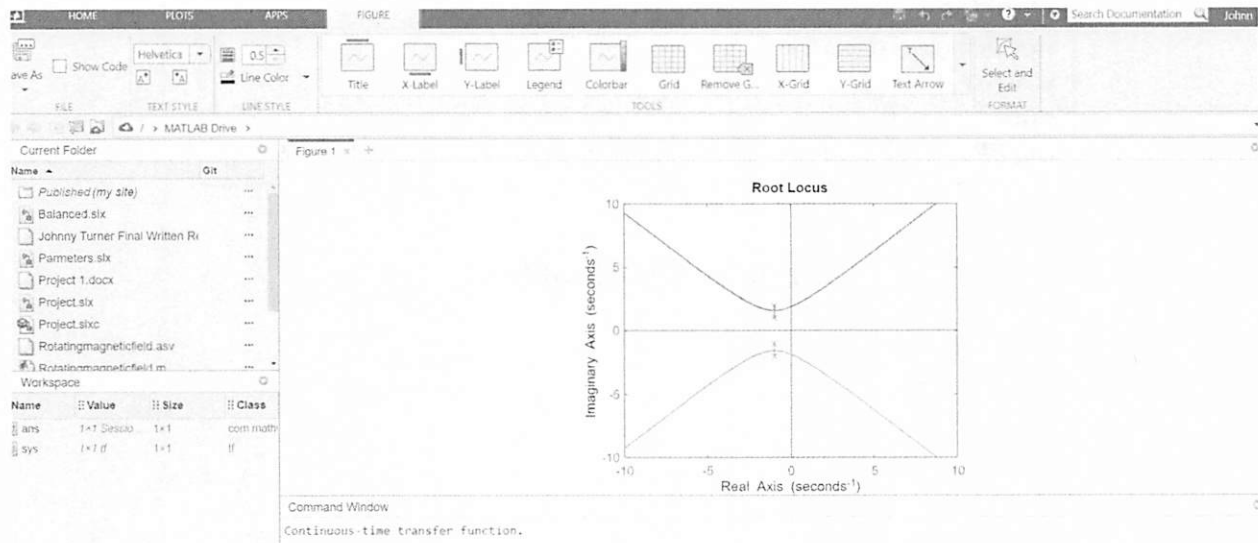


Figure 3: Simulation

Conclusion

In this assignment I was successfully able to simulate the plot for the root locus and their asymptotes for the given transfer function. I created a graphical representation in s-domain, and it is symmetrical about the real axis. Because the open loop poles and zeros exist in the s-domain having the values either as real or as complex conjugate pairs. Overall, this experiment, thought me how to breakdown the given code and have a understanding of how to find the root locus.

ASSIGNMENT #8

Electrical and Computer Engineering Department
Servomechanicsm and Control Systems/ ELEG 4307-P01
Assignment 8- spring 2022

Consider a unity-feedback control system with the following feedforward transfer function $G(s)$ given by:

$$G(s) = \frac{K(s + 1)}{(s^2 + 2s + 2)(s^2 + 2s + 5)}$$

Using MATLAB, write the code and plot the root locus diagram.

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

600

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Assignment 8- spring 2022

Consider a unity-feedback control system with the following feedforward transfer function $G(s)$ given by:

$$G(s) = \frac{K(s+1)}{(s^2+2s+2)(s^2+2s+5)}$$

Using MATLAB, write the code and plot the root locus diagram.



Matlab Code:

```
% Input the Numerator and Denominator in symbolic type
Numerator = str2sym( input('Enter the Numerator: ', 's') );
Denominator = str2sym( input('Enter the Denominator: ', 's') );

Second_order_system = Numerator / Denominator;

%Find Roots of the Numerator and Denominator
N = sym2poly(Numerator);
D = sym2poly(Denominator);

% Create the Transfer function
sys = tf(N,D);

% creates the root locus plot of the system
r = rlocusplot(sys);
hold on;

% finds zeros & poles
z = zero(sys);
p = pole(sys);

% finds the number of poles/zeros & the sum of them
lz = length(z);
lp = length(p);
Sz = sum(z);
Sp = sum(p);

% finds the difference in number of poles and zeros to calc asy angles
lpz = lp - lz;
switch lpz
    case 0
        Qasy = [];
    case 1
        Qasy = (-1) * pi;
    case 3
        Qasy = [-pi,-pi/3,pi/3];
    case 4
        Qasy = [-pi/4,pi/4,-3*pi/4, 3*pi/4];
    case 2
        Qasy = [pi/2,-pi/2];
    otherwise
        Qasy = [];
end

%find x intercept & plot the asyms
xinter = (Sp - Sz) / lpz;
m = tan(Qasy);
if (xinter>0)
    yinter = -m * abs(xinter);
end
```

```

if(xinter < 0)
    yinter = m * abs(xinter);
end
x = [-20:1:20];
y = x;
t = length(yinter);
while t>0
    y = m(t).*x + yinter(t);
    plot(x,y,'r--','LineWidth',0.5)
    hold on;
    t = t-1;
end
hold off;

```

Notes:

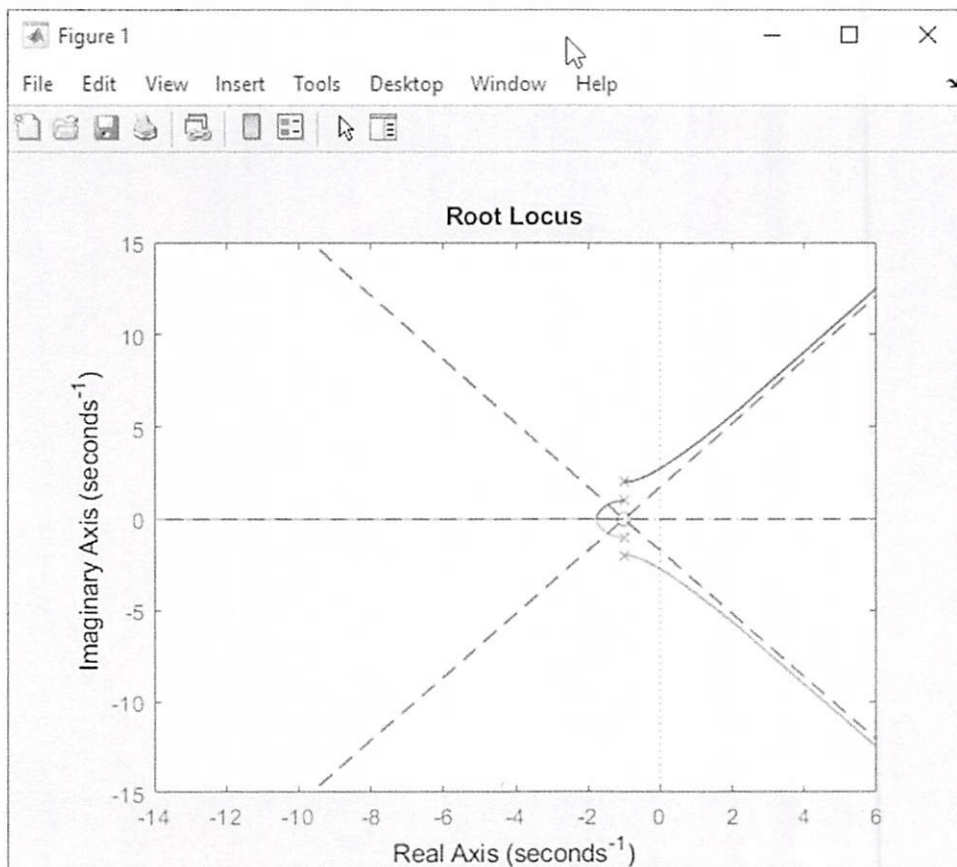
To use the above code enter the numerator and denominator when prompted without including the gain 'K' like below.

```

>> Assignment_8
Enter the Numerator: s+1
Enter the Denominator: (s^2 + 2*s + 2)*(s^2 + 2*s + 5)
>> |

```

You should get the correct output. It should look like below.



Comments:

I improved this code over the code in assignment 7. This is mostly in the form that positive x-intercepts for the asymptotic lines are graphed properly. Though in the above example it is not seen, but it does work.



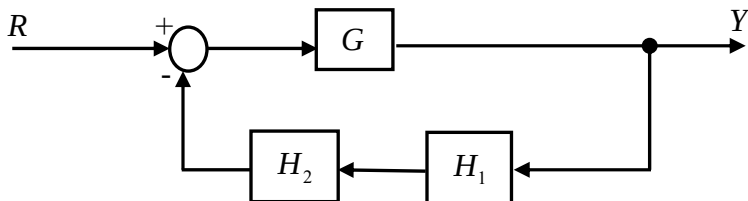
QUIZ #1

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Quiz 1- Spring 2022

First Name _____ Last _____

Show all your work including the formulas/equations to get full points

Reduce the block diagram of the control system below to a single block, and
then find $\frac{Y}{R}$?



SAMPLE WORK OF STUDENTS

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

ELEG-4307

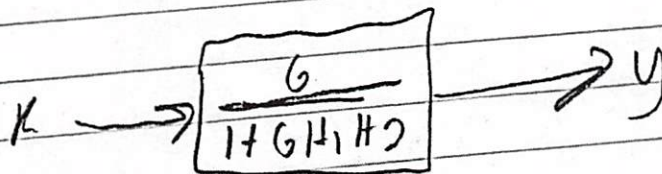
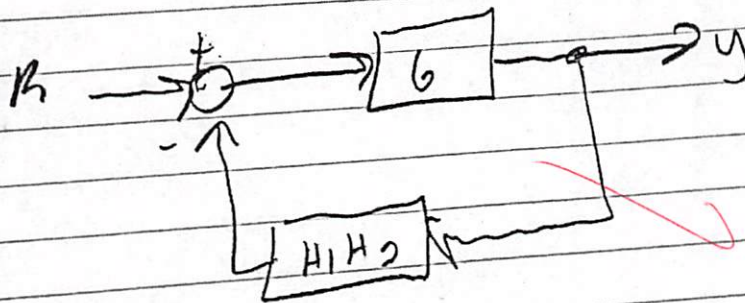
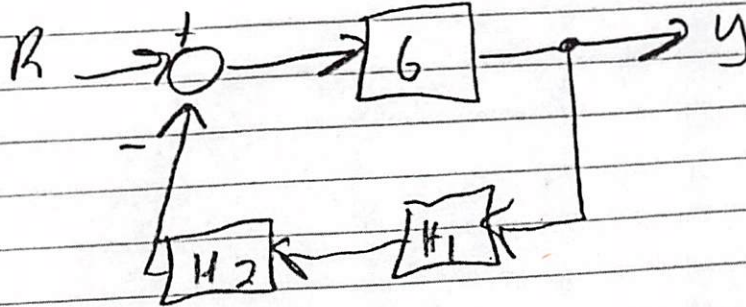
2/16/22

Quiz 1

600

"I have neither given nor received unauthorized assistance on this assignment" X Kites 7/22

1.)



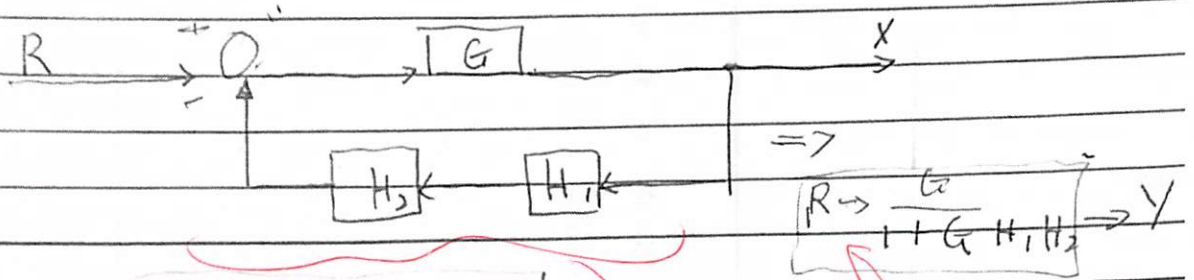
$$\frac{Y}{R} = \frac{G}{1 + GH_1H_2}$$

AVERAGE

ELEG 4307 - PO1
Ösöyge Ayerü

Quiz 1 - Spring 2022

95



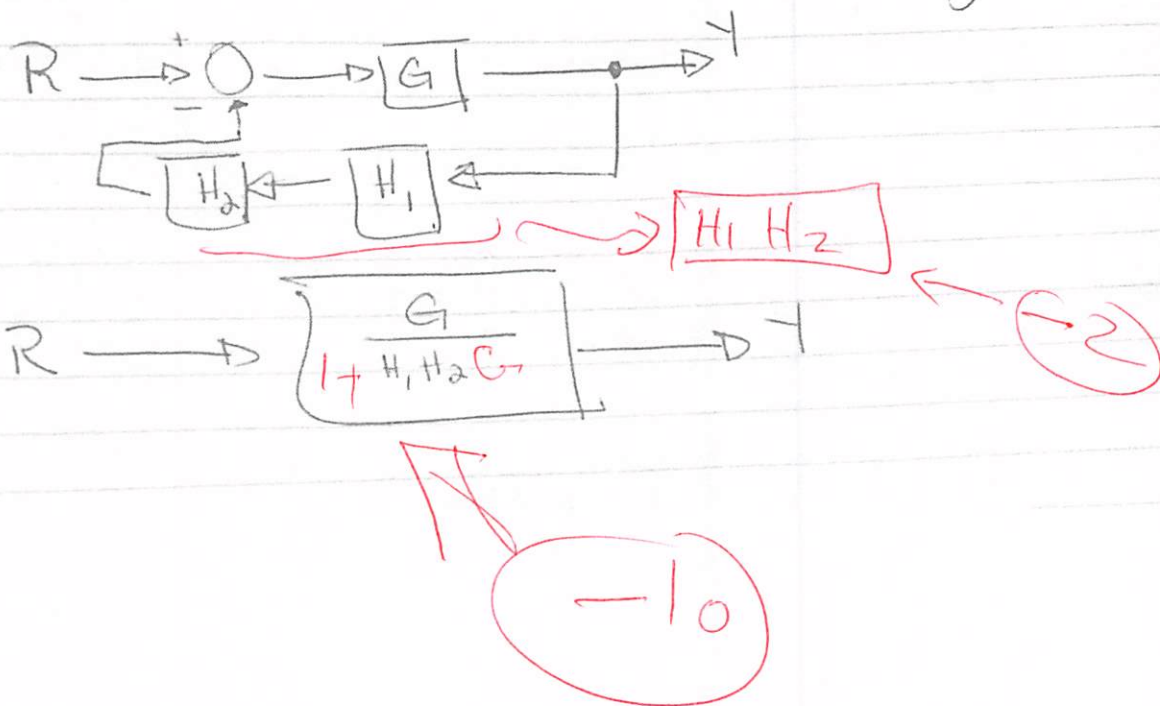
$$\frac{Y}{R} = \frac{G}{1 + (G H_1 H_2)}$$

1
3

2
 $H_1 H_2$

BELOW AVERAGE

88



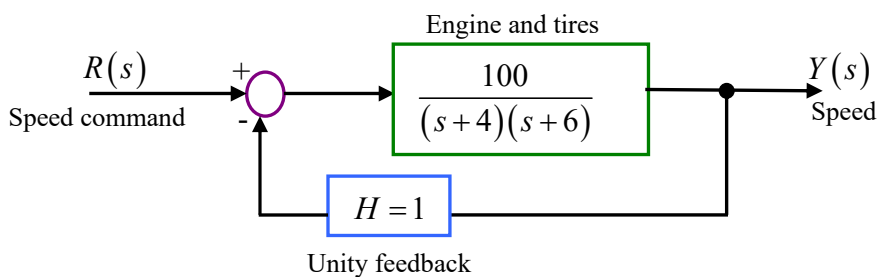
QUIZ #2

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Quiz 2- Spring 2022

First Name _____ Last _____

Show all your work including the formulas/equations to get full points

The engine, body, and tires of a racing vehicle affect the acceleration and speed attainable. The speed control of the car is represented by the model below:



- (a) Calculate the steady state error (e_{ss}) of the car to a step command in speed.
- (b) Calculate percent overshoot (P.O.) of the speed to a step command.

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

ELE6-4307

4/1/2022

QUIZ 2

1.) open loop:

$$G(s) = \frac{100}{(s+4)(s+6)}$$

closed loop:

$$T(s) = \frac{G(s)}{1+G(s)}$$

$$T(s) = \frac{100}{(s+4)(s+6)} \cdot \frac{1}{1 + \frac{100}{(s+4)(s+6)}}$$

$$T(s) = \frac{100}{(s+4)(s+6) + 100}$$

$$T(s) = \frac{100}{s^2 + 10s + 24 + 100}$$

$$T(s) = \frac{100}{s^2 + 10s + 124}$$

a.) steady state error:

$$\frac{Y(s)}{K(s)} = \frac{100}{s^2 + 10s + 124}$$

$$K(s) = 1/s$$

$$E(s) = K(s)[1 - T(s)]$$

$$E(s) = K(s) \left(1 - \frac{100}{s^2 + 10s + 124} \right)$$

$$E(s) = \frac{1}{s} * \frac{s^2 + 10s + 24}{s^2 + 10s + 124}$$

$$E(s) = \frac{s^2 + 10s + 24}{s(s^2 + 10s + 124)}$$

$$e(\infty) = \lim_{s \rightarrow 0} \frac{s^2 + 10s + 24}{s^2 + 10s + 124}$$

$$e(\infty) = \frac{24}{124}$$

$$e(\infty) = 0.194$$

$$T(s) = \frac{100}{(s^2 + 10s + 124) + 100} = \frac{100}{s^2 + 20s + 124}$$

$$\omega_n^2 = 100 + 124 = 124 \rightarrow \omega_n = \sqrt{124}$$

$$\text{Type 0} \rightarrow \text{step} \rightarrow e_s = \frac{1}{1+K_p}$$

$$K_p = \lim_{s \rightarrow 0} G(s)$$

$$K_p = \frac{100}{24} = 4.2$$

$$e_s = \frac{1}{1+4.2} = \frac{1}{5.2}$$

b.) Percent overshoot:

$$2\zeta\omega_n = 10 \Rightarrow \zeta = \frac{10}{2\omega_n} = \frac{10}{2\sqrt{124}}$$

$$\Rightarrow 0.45$$

$$MPO = e^{-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}} \times 100$$

$$= e^{-\frac{0.45\pi}{\sqrt{1-0.45^2}}} \times 100$$

$$= 20.53\%$$

AVERAGE

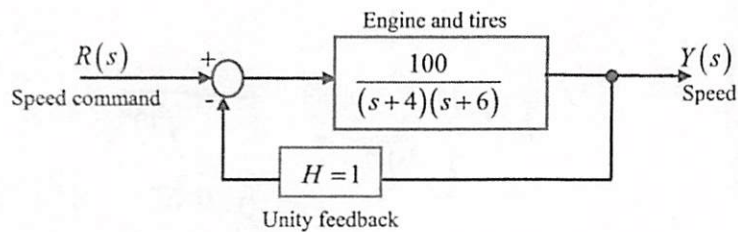
98

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Quiz 2- Spring 2022

First Name _____ Last _____

Show all your work including the formulas/equations to get full points

The engine, body, and tires of a racing vehicle affect the acceleration and speed attainable. The speed control of the car is represented by the model below:



- Calculate the steady state error (e_{ss}) of the car to a step command in speed.
- Calculate percent overshoot (P.O.) of the speed to a step command.

a) The closed loop transfer function

$$T(s) = \frac{Y(s)}{R(s)} = \frac{Y}{R}(s) = \frac{G(s)}{1 + G(s)H(s)}$$

$$T(s) = \frac{100}{s^2 + 10s + 24} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$\omega_n^2 = 100 + 24 = 124 \Rightarrow \omega_n = \sqrt{124}$$

Type 0 = step $\rightarrow$ $css = \frac{A}{1 + k_p}$, $k_p = \lim_{s \rightarrow 0} G(s)$

$$k_p = \frac{100}{24} = 4.2 \Rightarrow css = \frac{A}{1 + 4.2} = \boxed{\frac{A}{5.2}} \text{ is the steady state error}$$

b) The general second order transfer function is,

$$T(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$\omega_n^2 = 124$$

$$\omega_n = 11.13$$

$$\zeta = \frac{4.16}{2\omega_n} = \frac{4.16}{2 \times 11.13} = 0.18$$

$$2\zeta\omega_n = 10 \Rightarrow \zeta = \frac{10}{2 \cdot \omega_n} = \frac{10}{2 \cdot \sqrt{124}} = 0.45$$

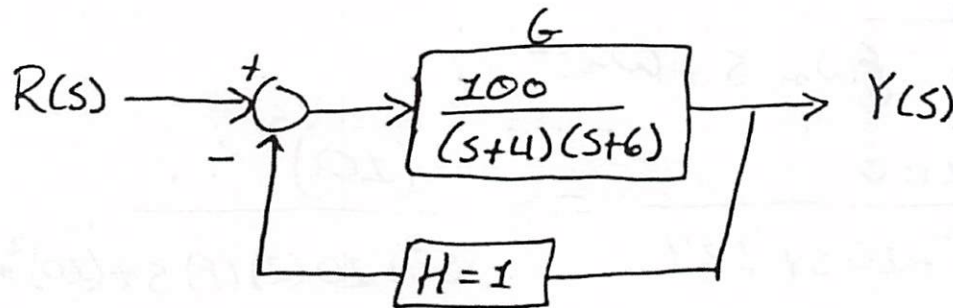
$$MPO = e^{-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}} \times 100$$

$$= e^{-\frac{\pi(0.18)}{\sqrt{1-0.18^2}}} \times 100$$

$$= \boxed{56.50\%} \rightarrow 21\%$$

BELOW AVERAGE

90 Quiz #2



a) ess to a step input

$$E(s) = Y(s) - R(s)$$

$$K_p = \lim_{s \rightarrow 0} G(s) = \frac{100}{24} = 4.2$$

$$Y(s) = \frac{G}{1+G} R(s) \Rightarrow \frac{100}{(s+4)(s+6)} R(s)$$

$$1 + \left(\frac{100}{(s+4)(s+6)} \right)$$

$$Y(s) = \frac{100}{s^2 + 10s + 24} \cdot R(s)$$

$$R(s) = A/s$$

$$e_{ss} = \frac{A}{1+K_p} = \frac{A}{1+4.2}$$

$$E(s) = \frac{100}{s^2 + 10s + 24} \cdot R(s)$$

$$E(s) = R \left(\frac{100}{s^2 + 10s + 24} - 1 \right)$$

$$e_{ss} = \frac{-6}{31}$$

$$e_{ss} = \lim_{s \rightarrow 0} \left(s \left(\frac{1}{s} \left(\frac{100}{s^2 + 10s + 24} - 1 \right) \right) \right)$$

$$e_{ss} = \lim_{s \rightarrow 0} \left(\frac{100}{s^2 + 10s + 24} - 1 \right) = \frac{-6}{31}$$

$$b) \text{MPO} = e^{-\left(f\pi/\sqrt{1-f^2}\right)} \times 100\%$$

$$T(s) = \frac{\omega_n^2}{s^2 + 2f\omega_n s + \omega_n^2}$$

$$T(s) = \frac{100}{s^2 + 10s + 124} \Rightarrow \frac{(10)^2}{s^2 + 10(2)(f)s + (10)^2 + 24}$$

$$\omega_n = 10$$

$$f = 1/2$$

$$10 = 10(2)f$$

$$f = \frac{10}{20} = 1/2$$

$$\text{MPO} = e^{-\left(\frac{1/2 \cdot \pi}{\sqrt{1-(1/2)^2}}\right)} \times 100\% = 16.303\%$$

$$\boxed{\text{MPO} = 16.303\%}$$



QUIZ #3

Electrical and Computer Engineering Department
Servomechanicsm and Control Systems/ ELEG 4307-P01
Quiz 3- Spring 2022

First Name_____ Last _____

Show all your work including the formulas/equations to get full points

Consider a control system whose characteristic equation is

$$Q(s) = s^4 + 2s^3 + 3s^2 + 4s + 3$$

- (a). Determine and show the number of sign changes in the first column based on the Routh array.
- (b). Determine and show the number of roots in the right half of the s-plane based on the Routh array.
- (c). Determine and explain the stability of the system using the Routh-Hurwitz criterion.

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

$$Q(s) = s^4 + 2s^3 + 3s^2 + 4s + 3$$

(a)

s^4	1	3	3	0
s^3	2	4	0	0
s^2	b_1	b_2	0	
s^1	c_1	c_2		
s^0	d_1			

$$b_1 = \frac{-\begin{vmatrix} 1 & 3 \\ 2 & 4 \end{vmatrix}}{2} = 1$$

$$b_2 = \frac{-\begin{vmatrix} 1 & 3 \\ 2 & 0 \end{vmatrix}}{2} = 3$$

First column =

1
2
1
-2
3

1 sign change
2 sign change

$$c_1 = \frac{-\begin{vmatrix} 2 & 4 \\ 1 & 3 \end{vmatrix}}{1} = -2$$

$$c_2 = \frac{-\begin{vmatrix} 2 & 0 \\ 1 & 0 \end{vmatrix}}{1} = 0$$

$$d_1 = \frac{-\begin{vmatrix} 1 & 3 \\ -2 & 0 \end{vmatrix}}{-2} = 3$$

2 sign changes
in first column

(b) # of roots on right half = # of sign changes so

2 roots on right half

(c) System is unstable since there are sign changes in first column

AVERAGE

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$$Q(s) = s^4 + 2s^3 + 3s^2 + 4s + 3$$

1. $\frac{0 - (-20)}{-5}$

$$\frac{4-6}{2} = \frac{-2}{2} = -1$$

s^4	1	3	3
s^3	2	4	0
s^2	-5	0	
s^1	4	0	
s^0			

- ① $\leftarrow +s^2$
- ② $\leftarrow -s^1$
- ③ $\leftarrow +s^0$

s^4	1	3	3
s^3	2	4	0
s^2	1	3	0
s^1	-2	0	
s^0	+3		

$$-\frac{0 - (-6)}{-2} = +3$$

2 sign changes

2. # of roots

2 positive roots on right-half

3. The system is unstable why? -3

BELOW AVERAGE

75

ELEG 4307

Quiz 3

$$Q(s) = s^4 + 2s^3 + 3s^2 + 4s + 3$$

s^4	1	0	3
s^3	2	4	0
s^2	$\frac{0-4}{2} = -2$	$\frac{6-0}{2} = 3$	
s^1	$[-2 \times 4] - [2 \times 3] = -7$		
s^0	3		

s^4	1	0	3
s^3	-2	4	
s^2	-2	3	
s^1	-7		
s^0	3		

④ no. of sign change
= 2

⑤ no. of roots in right half plane
= 2

⑥ Two roots lie in R.H.P
is unstable.

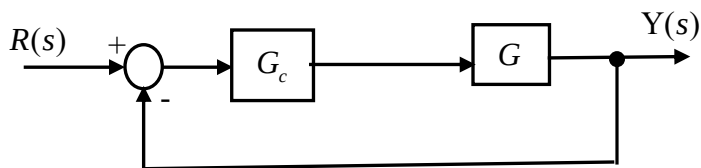
EXAM #1

Electrical and Computer Engineering Department
Servomechanicsm and Control Systems/ ELEG 4073-Z01
Exam 1- Spring 2021

First Name _____ Last _____

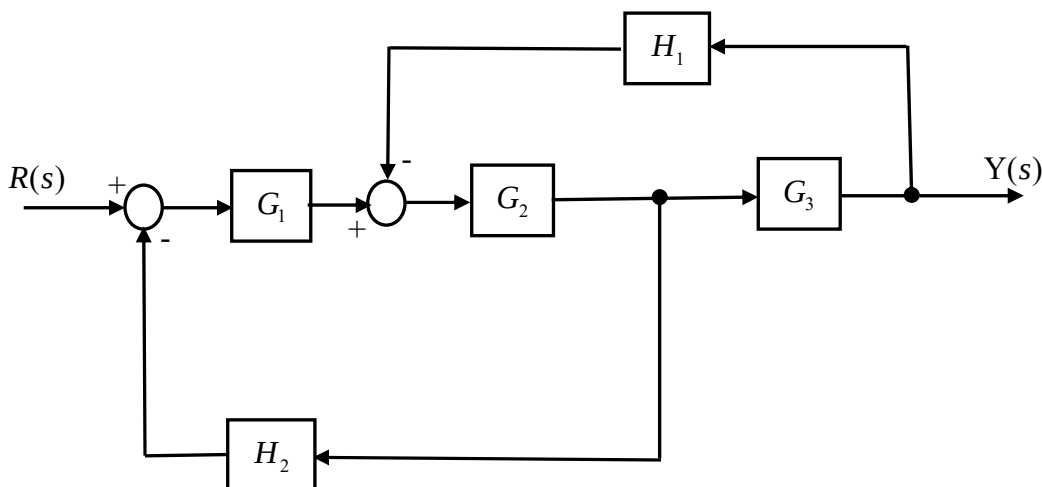
Show all your work including the formulas/equations to get full points

1. Given plant transfer function, $G = \frac{K}{\tau s + 1}$ and system transfer function, $T = \frac{G}{1+G}$. Find the sensitivity of T with respect to τ .
2. Given the below control system:



Where, $G_c = K$ and $G(s) = \frac{10}{s(s+2)}$. Determine the controller gain, K for the ramp input such that the steady state error is 1%.

3. Compute the transfer function $\frac{Y(s)}{R(s)}$ of the depicted block diagram by
 - (a) plotting the relevant Signal Flow Graph (SFG) and then
 - (b) applying Mason's gain formula.



SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

600

Electrical and Computer Engineering Department
ELEG 4307

Exam 1

First name: Osesiye

Last: Ayeni

(1) $G = \frac{k}{rs+1}$

$T = \frac{G}{1+G}$

$T = \frac{k}{rs+1} \cdot \frac{rs+1}{rs+1+k} = \frac{k}{rs+1+k}$

$T = \frac{k}{1+rs+k}$

Sensitivity of T

$S_r^T = \frac{\frac{\partial T}{\partial r}}{\frac{T}{r}} = \frac{\partial r}{\partial T} \cdot \frac{r}{T}$

$S_r^T = \frac{\partial r}{\partial T} \cdot \frac{r}{T}$

$S_r^T = \frac{(1+rs+k)(0) - k(0+rs(1)+0)}{(1+rs+k)^2} \cdot \frac{r}{\left[\frac{k}{1+rs+k} \right]}$

$= \frac{-k(s)}{(1+rs+k)^2} \cdot \frac{r(1+rs+k)}{k}$

$= \frac{-s \cdot r}{1+rs+k} = \frac{-rs}{1+rs+k}$

Ans = $\frac{-rs}{1+rs+k}$

$$(2) \quad G_c = K \quad G(s) = \frac{10}{s(s+2)}$$

$$G_{cu}(s) = G_c(s) \cdot G(s)$$

$$G_{cu}(s) = K \cdot \frac{10}{s(s+2)} = \frac{10K}{s(s+2)}$$

$$\text{input } r(t) = t^2 u(t)$$

$$R(s) = \frac{1}{s^3}$$

$$\text{ramp input} = \frac{1}{K_v}$$

$$= \frac{1}{\lim_{s \rightarrow 0} s \cdot G_{cu}(s)} = \frac{1}{\lim_{s \rightarrow 0} s \cdot \frac{10K}{s(s+2)}}$$

$$e_{ss} = \frac{(s+2)}{\lim_{s \rightarrow 0} 10K} = 0.001$$

$$\frac{2}{10K} \times 0.01$$

$$0.01(10K) = 2$$

$$0.01 \quad 0.01$$

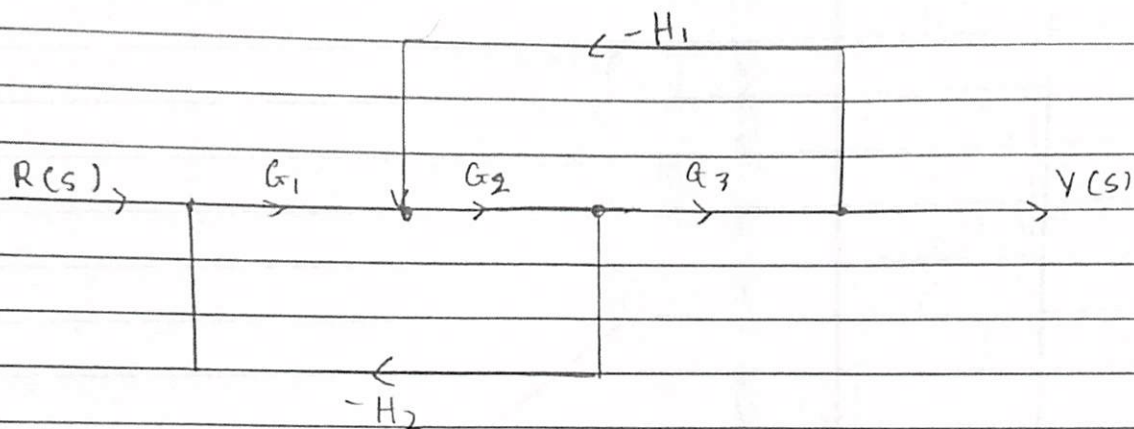
$$10K = 200$$

$$10 \quad 10$$

$$K = 20$$

(3)

(a)



(b) Applying Mason's gain formula

$$\text{forward gain} = G_1 G_2 G_3$$

$$\text{loop gain 1} = -G_2 G_3 H_1$$

$$\text{loop gain 2} = -G_1 G_2 H_2$$

$$\frac{Y(s)}{R(s)} = \frac{G_1 G_2 G_3}{1 + G_2 G_3 H_1 + G_1 G_2 H_2}$$

$$T(s) = \frac{P_1 \Delta_1}{\Delta} = \frac{G_1 G_2 G_3}{1 - \sum (\text{loop gain 1}) + \sum (\text{loop gain 2})}$$

$$T(s) = \frac{G_1 G_2 G_3}{1 + G_1 G_2 H_2 + G_2 G_3 H_1}$$

L_1 and L_2 are touching each other for both loops

$$(4) \quad G(s) = \frac{k}{s(s+P)}$$

$$PO = 4.5\% \quad t_s = 3$$

Solution

$$1 + G(s)h(s) = 0$$

$$1 + \frac{k}{s(s+P)}$$

$$s^2 + Ps + k = 0$$

$$2\xi\omega_n = P$$

$$m_p = e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}} \times 100}$$

$$0.045 = e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}}}$$

$$-3.10109 = \frac{-\pi\xi}{\sqrt{1-\xi^2}}$$

$$0.98757 = \frac{\xi}{\sqrt{1-\xi^2}}$$

$$0.9875(\sqrt{1-\xi^2}) = \xi$$

$$0.975156(1-\xi^2) = \xi^2$$

$$0.97515 = 1.97515\xi^2$$

$$\xi^2 = 0.49370$$

$$\xi = 0.7026$$

$$t_s = 3 \text{ sec}$$

$$\frac{4}{\xi\omega_n} = 3$$

$$\xi\omega_n = \frac{4}{3} = 1.33$$

$$P = 2\xi\omega_n = 2 \times 1.33$$

$$P = 2.66 \text{ Ans}$$

$$2 \times 0.7026 \times \omega_n = 2.66$$

$$\omega_n = 1.89296$$

$$k = \omega_n^2 = (1.89296)^2$$

$$k = 3.5833 \text{ Ans}$$

AVERAGE

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1) $G = K$ Exgm

$$T = \frac{G}{1+G}$$

$$T = \frac{K}{1+\gamma S+1} = \frac{K}{\gamma S+1}$$

$$S_\gamma^T = \frac{\% \text{ change in } T}{\% \text{ change in } \gamma}$$

$$= \frac{\frac{\partial T}{\partial \gamma}}{T} = \frac{\partial T}{\partial \gamma} \cdot \frac{\gamma}{T}$$

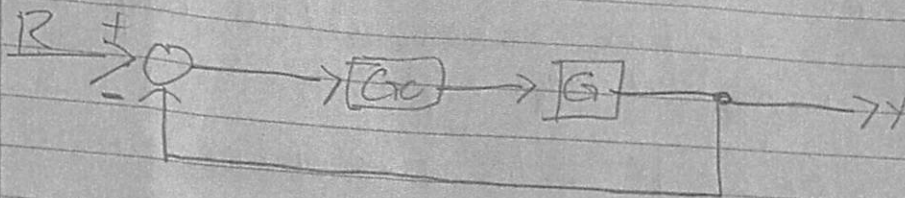
$$S_\gamma^T = \frac{(1+\gamma S+K)(0) - K(0+\gamma S(1)+0)}{(1+\gamma S+K)^2} \cdot \frac{\gamma}{\frac{K}{1+\gamma S+K}}$$

$$= \frac{-K(0)}{(1+\gamma S+K)^2} \cdot \frac{\gamma(1+\gamma S+K)}{K}$$

$$= -\frac{\gamma S}{1+\gamma S+K}$$

$$S_\gamma^T = \frac{-\gamma S}{1+\gamma S+K}$$

2 Given



$$G_c = K, G(s) = \frac{10}{s(s+2)}$$

Find the controller gain (G_c), K for ramp input such that steady state error (ess) is 1%.

Solution

For ramp input $(s) = \frac{1}{s^2}$
 $e_{ss} = 0.01$

$$E(s) = R(1-T) = \frac{1}{s^2} \left(1 - \frac{G G_c}{1 + G G_c} \right) = \frac{1}{s^2} \left(\frac{1}{1 + G G_c} \right)$$

$$1 + G G_c = 1 + \frac{10K}{s(s+2)} = \frac{s(s+2) + 10K}{s(s+2)}$$

$$E(s) = \frac{1}{s^2} \left(\frac{s(s+2)}{s(s+2) + 10K} \right)$$

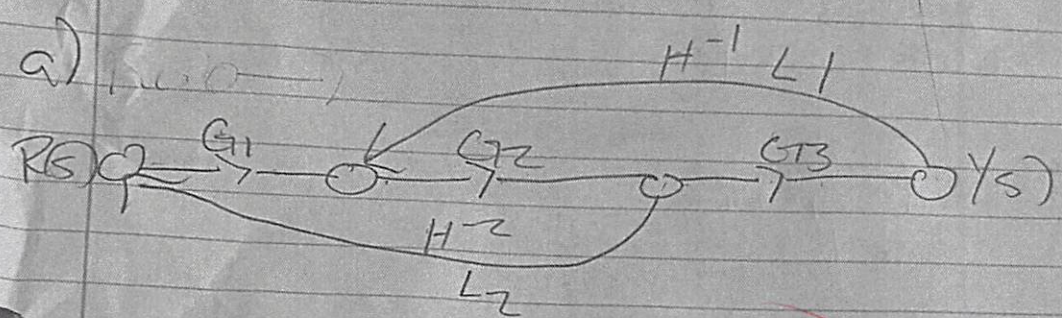
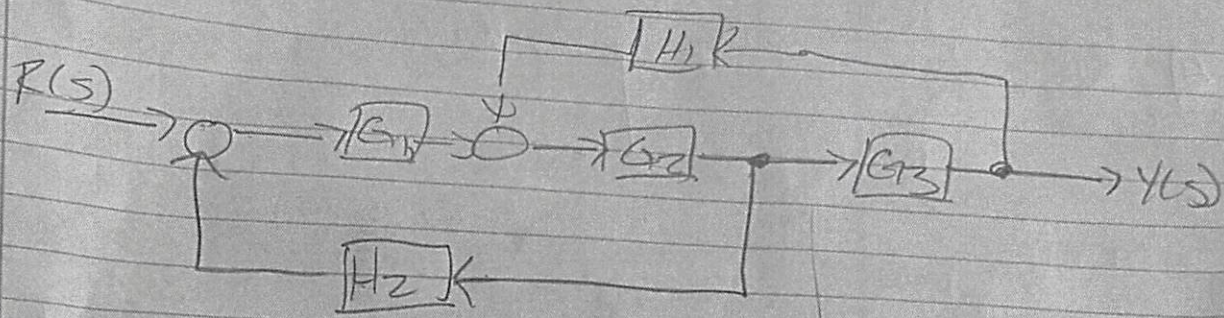
$$= \frac{1}{s} \left(\frac{s+2}{s(s+2) + 10K} \right)$$

$$e_{ss} = \lim_{s \rightarrow 0} (s E(s)) = \lim_{s \rightarrow 0} \left(\frac{1}{0(0+2) + 10K} \right)$$

$$e_{ss} = \frac{2}{10K}$$

$$e_{ss} = 0.01 = \frac{1}{5K} \quad K = 20$$

3)



b)
$$T(s) = \frac{Y(s)}{R(s)} = \frac{\sum (P_i K_i)}{\Delta} = \frac{P_1 \Delta_1}{\Delta}$$

$$P_1 = G_1 G_2 G_3$$

$$\Delta = 1 - \sum L_n + \sum L_n L_m$$

$$\sum L_n = L_1 + L_2$$

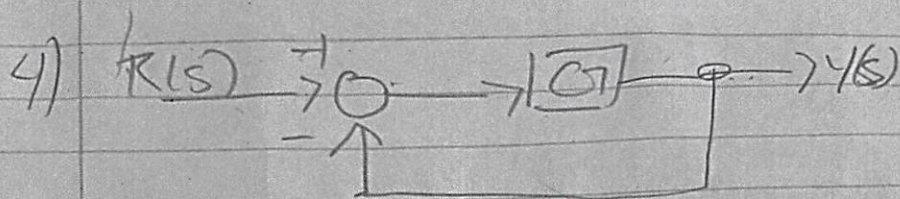
$$\sum L_n L_m = L_1 L_2 = 0$$

$$L_1 = -G_2 G_3 H_1$$

$$L_2 = -G_1 G_2 H_2$$

$$\Delta_1 = 1$$

$$T_s = \frac{G_1 G_2 G_3 (1)}{1 + G_2 G_3 H_1 + (-G_1 G_2 H_2)}$$



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

$$\alpha = \ln \frac{400}{10} = \ln \frac{100}{4.5} = 3.101$$

$$\zeta = \frac{\alpha}{\sqrt{\alpha^2 + \pi^2}} = \frac{3.101}{\sqrt{3.101^2 + \pi^2}} = 0.702$$

$$\omega_n = \frac{4}{\zeta T_s} = \frac{4}{0.702(3)} = 1.898$$

$$P = 2\zeta\omega_n = 2(0.702)(1.898) = 2.665$$

$$K = \omega_n^2 = (1.898)^2 = 3.602$$

BELOW AVERAGE

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ELEG 4307

Exam 1

1. Given plant transfer function, $G = \frac{k}{s+1}$ and system transfer function, $T = \frac{G}{1+G}$. Find the sensitivity of T with respect to T .

Answer:-

$$G = \frac{k}{s+1} \quad T = \frac{G}{1+G}$$

$$\frac{\partial T}{\partial s} = \frac{(1)(1+G) - G(1)}{(1+G)^2} = \frac{1}{(1+G)^2}$$

$$S_G^T = \frac{G}{T} \left(\frac{\partial T}{\partial G} \right) = \frac{1}{(1+G)} \cdot \frac{1}{G} = \frac{1}{1+G} = \frac{1}{s+1+k}$$

$$\{ S_T^T = S_G^T S_C^T \}$$

$$\{ S_G^T = \frac{s+1}{s+1+k} \}$$

$$G = \frac{k}{s+1} \rightarrow \frac{\partial G}{\partial T} = \frac{k}{(s+1)^2}$$

$$S_T^G = \left(\frac{\partial G}{\partial T} \right) \frac{T}{G} = \frac{-k}{(s+1)^2} \cdot \frac{s+1}{k} = \frac{-1}{s+1}$$

$$S_T^T = S_G^T S_C^T = \left(\frac{1}{s+1+k} \right) \left(\frac{-1}{s+1} \right) = \frac{-1}{(s+1)(s+1+k)}$$

2. Given the below control system:



Where, $G_c = k$ and $G(s) = \frac{s+2}{s^2}$. Determine the controller gain, k for the ramp input such that the steady state error is 1%

$$e_{ss} = 1\% = 0.01$$

$$r_{\text{ramp}}(s) = \frac{1}{s^2}$$

$$E(s) = R(1-T)$$

$$= \frac{1}{s^2} \left(1 - \frac{G_c G}{1 + G_c G} \right) = \frac{1}{s^2} \left(\frac{1}{1 + G_c G} \right) \left\{ 1 + G_c = 1 + \frac{10k}{s(s+2)} \right\}$$

$$= \frac{1}{s^2} \left(\frac{s(s+2)}{s(s+2) + 10k} \right)$$

$$= \frac{1}{s} \left(\frac{s+2}{s(s+2) + 10k} \right)$$

$$e_{ss} = \lim_{s \rightarrow 0} s E(s)$$

$$= \lim_{s \rightarrow 0} s \left(\frac{1}{s} \cdot \frac{s+2}{s(s+2) + 10k} \right)$$

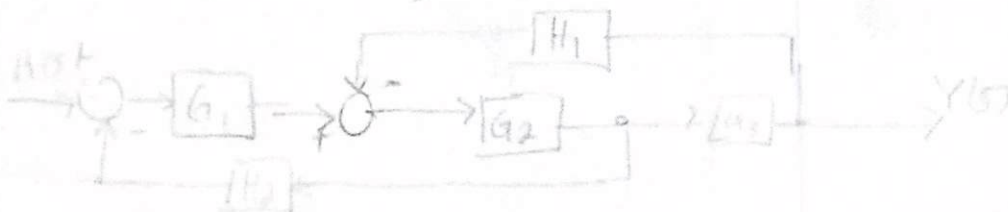
$$= \frac{s+2}{s(s+2) + 10k}$$

$$= \frac{2}{10k} = \frac{1}{5k}$$

$$e_{ss} = 0.01 = \frac{1}{5k} \Rightarrow \frac{1}{5k} = 0.01$$

$$k = 20$$

3. Compute the transfer function $\frac{Y(s)}{U(s)}$ of the depicted block diagram by
- plotting the relevant Signal Flow Graph (SFG) and then
 - applying Mason's gain formula.



a)

→ 20

4. Given the below control system:



Where, $G(s) = \frac{k}{s(s+p)}$. Determine the gain (k) and the pole (p) such that $PO = 4.5\%$ and $t_r = 3$

Answer:

$$\alpha = \ln \frac{100}{PO} = \ln \frac{100}{4.5} = 3.101$$

$$\beta = \frac{\alpha}{\sqrt{k+1}} = \frac{3.101}{\sqrt{3.101^2 + 1}} = 0.702$$

$$\omega_n = \frac{t_r}{\beta} = \frac{3}{(0.702)(3)} = 1.425$$

$$T = \frac{3.101}{\omega_n} = \frac{3.101}{1.425} = 2.176$$

$$K = \omega_n^2 = 1.425^2 = 2.03$$

$$T = 2.3 \omega_n = 2.3(1.425) = 3.278$$

EXAM #2

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4073-P01
Exam 2- Spring 2022

First Name _____ Last _____

Show all your work including the formulas/equations to get full points

Construct a root-locus diagram of the control system with the following open-loop transfer function:

$$HG(s) = \frac{K(s+2)}{s^4}$$

When you sketch the root locus, you must find and show each of the following:

- (a). Zeros and poles
- (b). Angles of the asymptotes
- (c). Intersection of the asymptotes with real axis
- (d). Angles of departure and arrival
- (e). Breakin/breakaway points
- (f). Angles between branches at breakin and breakaway points
- (g). Indicate by arrows the direction of the branches with increasing k
- (h). Parts of the real axis which are part of the locus

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

100

$$D) H(s) = \frac{K(s+2)}{s^4}$$

$$z_1 = -2$$

$$p_1 = p_2 = p_3 = p_4 = 0$$

$$p_H - z_H = 4 - 1 = 3$$

$$\phi_{asy} = -\pi, \pm \pi/3$$

$$= -180^\circ \pm 60^\circ$$

$$\sigma_c = \frac{\sum p - \sum z}{3} = \frac{0 - (-2)}{3} = \frac{2}{3} = 0.67$$

y = # of poles

$$\text{Break} = \frac{\pm 180}{y} = \frac{\pm 180}{4} = \pm 45^\circ$$

$$\alpha_{arrive} = \frac{\pm 360}{y} = \frac{\pm 360}{4} = \pm 90^\circ$$

For Breakings point

$$-K = s^4$$

$$(s+2)$$

$$-dK = \frac{(s+2)(4s^3) - s^4(1)}{(s+2)^2} = 0$$

$$4s^4 + 8s^3 - s^4 = 0$$

$$3s^4 + 8s^3 = 0$$

$$s^3(3s+8) = 0$$

$$s_1 = -\frac{8}{3} \text{ breakin point}$$

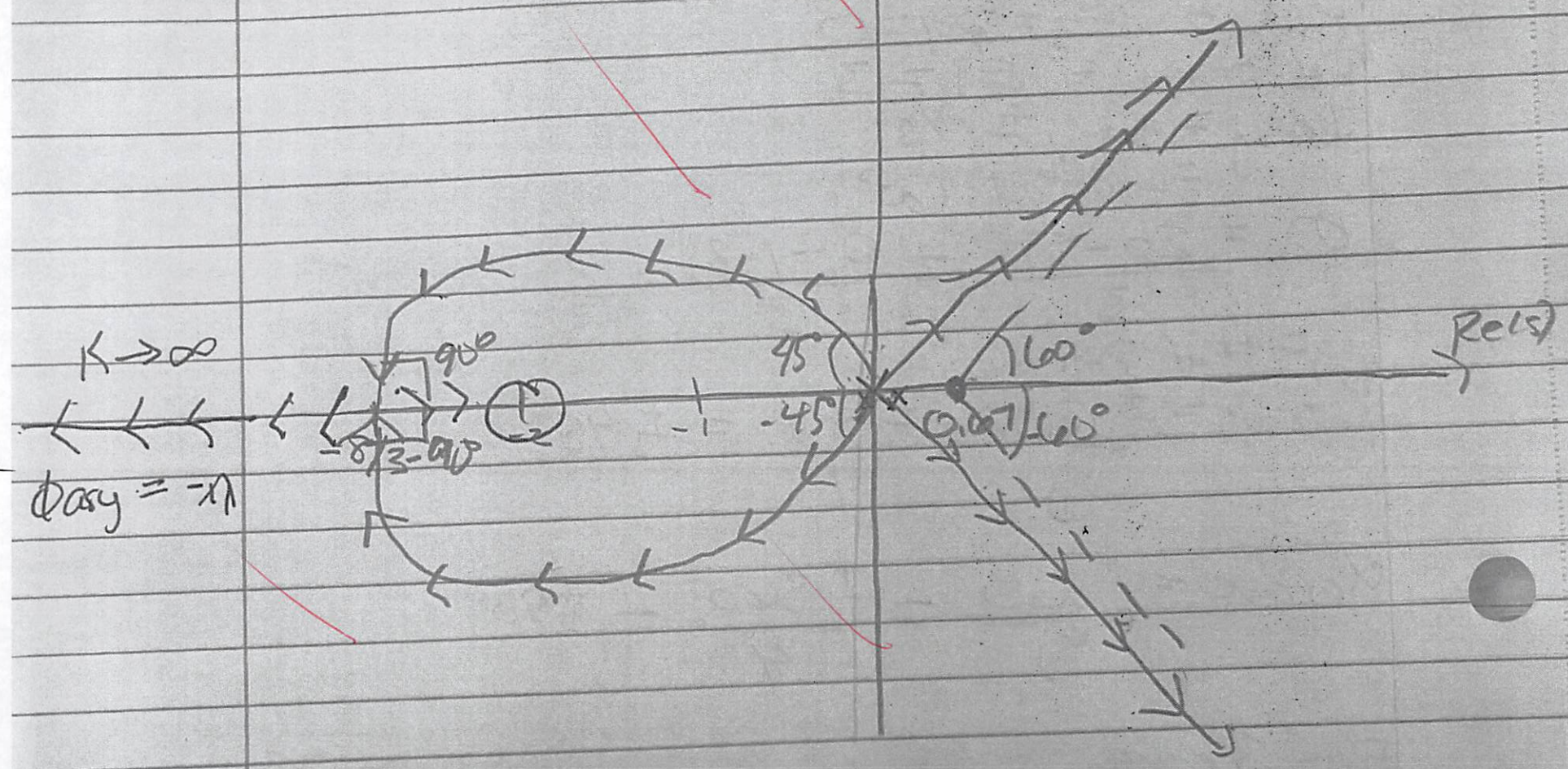
$$s' = 0 \text{ Breakaway point}$$

iv

Roots
Locus

Im(s)

Re(s)



AVERAGE

Exam 2

Construct a root-locus diagram of the control system with the following open-loop transfer function.

$$HG(s) = \frac{k(s+2)}{s^4}$$

When you sketch the root locus, you must find:

(a) zeroes: $2, -2$; Poles: $P_1 = P_2 = P_3 = P_4 = 0$

(b) $P_n - z_b = 4 - 1 = 3$; $\phi_{asy} = -\pi, \pm \pi/3 \Rightarrow -180^\circ, \pm 60^\circ$

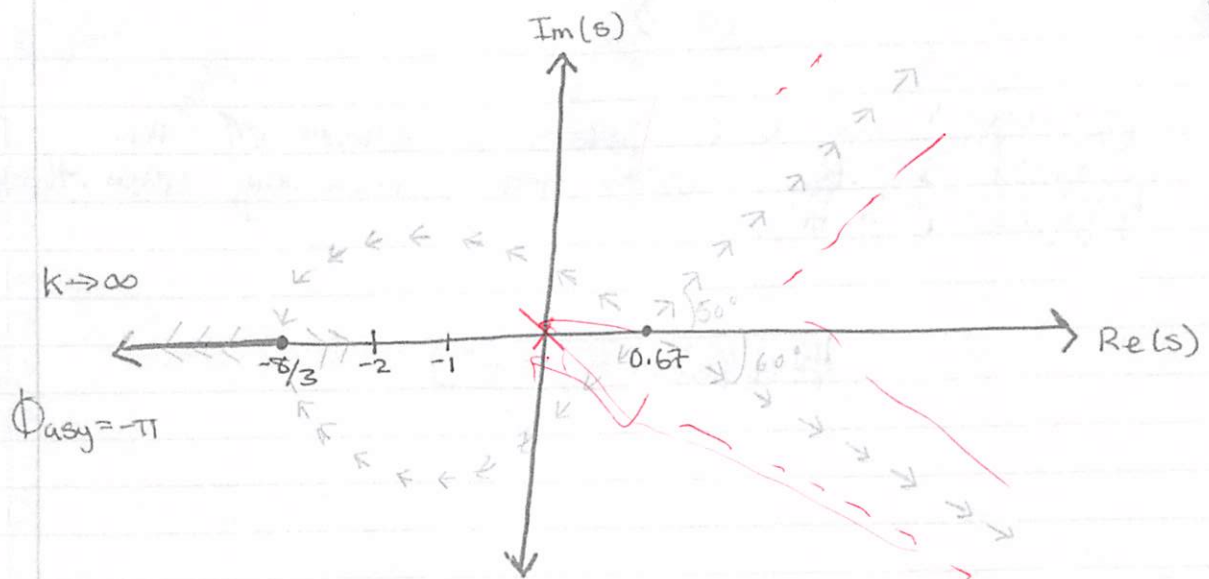
(c) $\zeta_c = \frac{\sum p - \sum z}{P_n - z_b} = \frac{0 - (-2)}{3} = \frac{2}{3} \approx 0.67$

(d) $\theta_{angle}^{dep} = \pm \frac{180}{4} = \pm 45^\circ$; $\theta_{arrival} = \pm \frac{360}{4} = \pm 90^\circ$

(e) BP $\rightarrow \frac{dk}{ds} \rightarrow 0 \rightarrow -k \rightarrow \frac{s^4}{(s+2)} \rightarrow \frac{-dk}{ds} = \frac{(s+2)(4s^3) - (s^4)(1)}{(s+2)^2} = 0$

$$4s^4 + 8s^3 - s^4 = 0 \rightarrow 3s^4 + 8s^3 = 0 \rightarrow s^3(2s+8) = 0$$

$s_1 = \left(-\frac{8}{3}\right)$ Break point; $(s=0)$ Breaking point



EXAM #3

Electrical and Computer Engineering Department
Servomechanisms and Control Systems/ ELEG 4307-P01
Exam 3- Spring 2022

First Name _____ Last _____

Show all your work including the formulas/equations to get full points

Consider the transfer function:

$$HG(s) = \frac{27 \left(1 + \frac{s}{2}\right)^2}{s^3 \left(1 + \frac{s}{40}\right)^2 \left(1 + \frac{s}{20}\right)}$$

Find the following:

- (a). $HG(j\omega)$
- (b). $20\log|HG(j\omega)|$
- (c). the value of k which is the extension point on 0 dB before first break frequency
- (d). the first break frequency, second break frequency, and third break frequency
- (e). $\phi(\omega) = \angle HG(j\omega)$
- (f). $\phi(\omega_c) = \angle HG(j\omega_c)$ at $\omega_c = 7 \text{ rad/sec}$.
- (g). the phase margin, ϕ_{PM}
- (h). is the system stable or not, explain?
- (i). the damping ration, ξ

SAMPLE WORK OF STUDENTS

ABOVE AVERAGE

Exam 3:

$$H(s) = \frac{27(1 + \frac{s}{2})^2}{s^3(1 + \frac{s}{40})^2(1 + \frac{s}{20})}$$

(a.) $H(j\omega)$:

$$\Rightarrow \frac{(1 + \frac{j\omega}{2})^2}{(\frac{j\omega}{3})^3(1 + \frac{j\omega}{40})^2(1 + \frac{j\omega}{20})}$$

(b.) $20 \log |H(j\omega)| = -60 \log |\frac{j\omega}{3}| + 40 \log |1 + \frac{j\omega}{2}|$
 $- 20 \log |1 + \frac{j\omega}{20}| - 40 \log |1 + \frac{j\omega}{40}|$

(c.) $K = 3$

(d.) Breakpoints:

1st $\rightarrow 2$

2nd $\rightarrow 20$

3rd $\rightarrow 40$

(e.)

$$\phi(\omega) = -270 + 2 \tan^{-1} \frac{\omega}{2} - \tan^{-1} \frac{\omega}{20} - 2 \tan^{-1} \frac{\omega}{40}$$

(f.)

$$\phi(\omega_c) = -270 + 2 \tan^{-1} \frac{7}{2} - \tan^{-1} \frac{7}{20} - 2 \tan^{-1} \frac{7}{40} = -161.05^\circ$$

(g.)

$$\phi_{pn} = 180^\circ + \phi(\omega_c) = 180 - 161.05^\circ = 18.19^\circ$$

(h.) The system is stable because $\phi_{pn} > 0$

(i.) Damping ratio, $\zeta = \phi_{pn} \cdot QG1 = 18.19 \cdot 0.01 = 0.1819$

AVERAGE

MUSA
4/29/22

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Servo Exam 3

$$H(s) = \frac{27(1+\frac{s}{2})^2}{s^2(1+\frac{s}{40})^2(1+\frac{s}{20})}$$

$$a) H(j\omega) \Rightarrow \frac{27(1+\frac{j\omega}{2})^2}{(j\omega)^2(1+\frac{j\omega}{40})^2(1+\frac{j\omega}{20})} = \frac{27(1+\frac{j\omega}{2})^2}{- \omega^2(1+\frac{j\omega}{40})^2(1+\frac{j\omega}{20})}$$

$$b) 20 \log |H(j\omega)| \Rightarrow H(j\omega) = \frac{27(1+\frac{\omega^2}{4})}{\omega^2(1+\frac{\omega^2}{1600})(1+\frac{\omega^2}{400})^{1/2}}$$

$$\text{So, } 20 \log |H(j\omega)| = 20 \log 27 + 20 \log (1+\frac{\omega^2}{4}) - (20 \cdot 3) \log (\omega) - 20 \log (1+\frac{\omega^2}{1600}) - (20/2) \log (1+\frac{\omega^2}{400})$$

c) Value of K which is ext. point

$$20 \log (27) = K \quad K = 14.3188$$

d) 1st/2nd/3rd break frequency

$$\omega = 2, 40, 20 \Rightarrow \omega_1 = 2, \omega_2 = 40, \omega_3 = 20$$

e) $\phi(\omega) = \angle H(j\omega)$

$$2 \tan^{-1} \frac{\omega}{2} + \tan^{-1} \frac{\omega}{40} - 180 - \tan^{-1} \frac{\omega}{20}$$

f) $\phi(\omega_c) = \angle H(j\omega_c)$ @ $\omega_c = 7 \text{ rad/sec}$

$$\tan^{-1} \frac{7}{2} + \tan^{-1} \frac{7}{40} - 180 - \tan^{-1} \frac{7}{20} = -115.31^\circ$$

g) Phase margin, $\phi_{pr} = 180^\circ - 115.31^\circ = 64.69^\circ$

h) System is stable because $\phi_{pr} > 0$

i) Damping ratio, $\zeta = \phi_{pr} \cdot 0.01 = 64.69^\circ \cdot 0.01 = 0.6469$

BELOW AVERAGE

61

$$H_G(s) = \frac{27 \left(1 + \frac{s}{2}\right)^2}{s^3 \left(1 + \frac{s}{40}\right)^2 \left(1 + \frac{s}{20}\right)}$$

$$a. \quad H_G(j\omega) = \frac{27 \left(1 + \frac{j\omega}{2}\right)^2}{(j\omega)^3 \left(1 + \frac{j\omega}{40}\right)^2 \left(1 + \frac{j\omega}{20}\right)}$$

$$b. \quad 20 \log_{10} |H_G(j\omega)| = 20 \log_{10} \left| \frac{27 \left(1 + \frac{j\omega}{2}\right)^2}{(j\omega)^3 \left(1 + \frac{j\omega}{40}\right)^2 \left(1 + \frac{j\omega}{20}\right)} \right|$$

$$= 28.627 + 10 \log_{10} \left(\left(1 - \frac{\omega^2}{4}\right)^2 + \omega^2 \right) - 60 \log_{10}(\omega) \\ - 10 \log_{10} \left(\left(1 - \frac{\omega^2}{1600}\right)^2 + \frac{\omega^2}{400} \right) - 10 \log_{10} \left(1 + \frac{\omega^2}{400} \right)$$

$$c. \quad |H_G(j\omega)|_{dB} = 0_{dB} \Rightarrow |H_G(j\omega)| = 1$$

? $K=3$

3

$$\left| \frac{27 \left(1 + \frac{j\omega}{2}\right)^2}{(j\omega)^3 \left(1 + \frac{j\omega}{40}\right)^2 \left(1 + \frac{j\omega}{20}\right)} \right| = 1$$

$$\frac{27 \left(\left(1 - \frac{\omega^2}{4}\right)^2 + \omega^2 \right)}{\omega^3 \left(\left(1 - \frac{\omega^2}{1600}\right)^2 + \frac{\omega^2}{400} \right) \left(1 + \frac{\omega^2}{400} \right)} = 1$$

$$\omega = 6.75 \text{ rad/s}$$

$$\omega = 6.75 \text{ rad/s}$$

2) First at $\omega = 0 \text{ rad/s}$
 Second at $\omega = 2 \text{ rad/s}$
 Third at $\omega = 20 \text{ rad/s}$

→ 6

e) $\Phi(\omega) = \angle H G(j\omega)$

→ 5
$$= \tan^{-1}\left(\frac{\omega}{1 - \frac{\omega^2}{4}}\right) + 90^\circ - \tan^{-1}\left(\frac{\omega/20}{1 - \frac{\omega^2}{1600}}\right) - \tan^{-1}\left(\frac{\omega}{20}\right)$$

f) $\Phi(\omega)|_{\omega=7} = -161^\circ$

g

-6

h

-10

i

-5