Wentworth Institute of Technology
Electrical Engineering and Technology

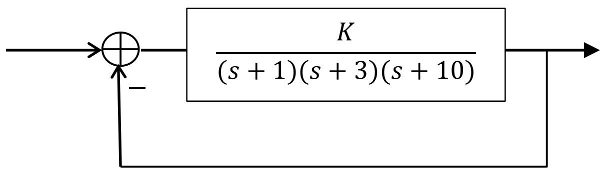
ELEC 820: Feedback and Control
Lab #4: Design of PID Controllers

Objective:

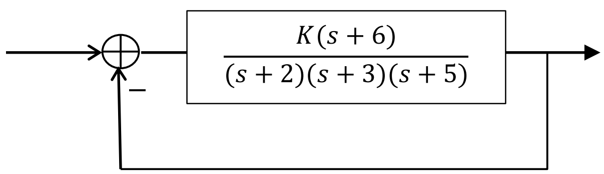
- To design PI, PD, and PID controllers using Root Locus

Design Problems:

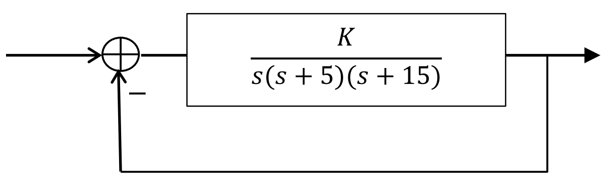
1. **PI Controller Design (4 points):** Design a PI controller to drive the step response error to zero. The system should operate with a percent overshoot of 30%.



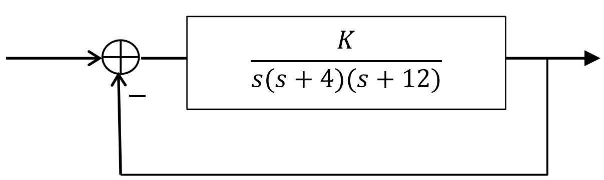
2. **PD Controller Design (4 points):** The following system operates with a dominant-pole damping ratio of 0.707. Design a PD controller so that the settling time is reduced by a factor of 2.



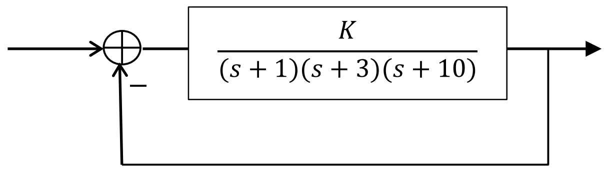
3. **PD Controller Design (4 points):** Design a PD controller for the system shown below to reduce the settling time by a factor of 4 while continuing to operate with 20% overshoot.



4. **PID Controller Design (8 points):** Design a PID controller for the system shown below to operate with a peak time that is two-thirds of the uncompensated system at 20% overshoot and with zero steady-state error for a step input.



Complete the tables and Provide detailed hand computations for the key steps of all PD designs in Problems 2~4: (θ, z_c, K)

<table>
<tr>
<td>Problem 1</td>
<td>Design a <u>PI</u> controller to drive the step response error to zero. The system should operate with a percent overshoot of 30%.


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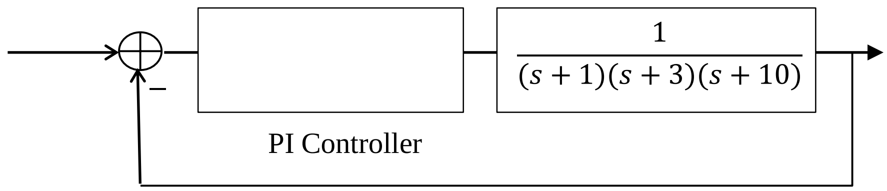
<tr>
<td>The PI-Compensated system</td>
<td>

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<tr>
<td>Plot the step responses of the original and the PI-compensated systems together</td>
<td></td>
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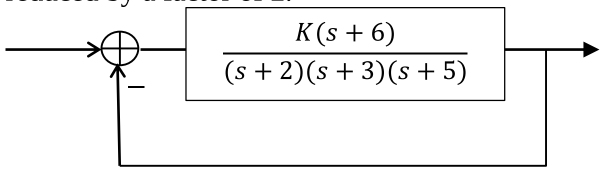
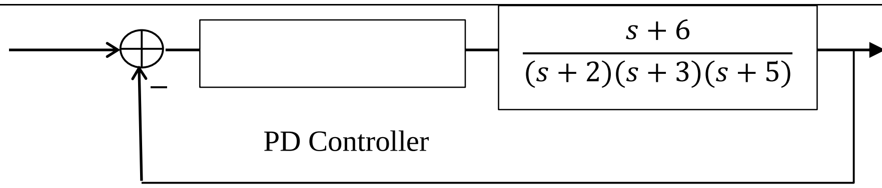
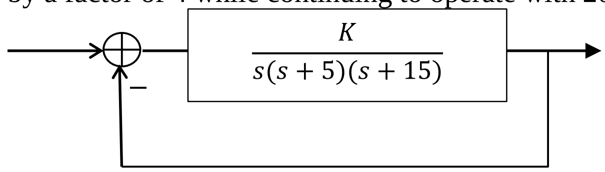
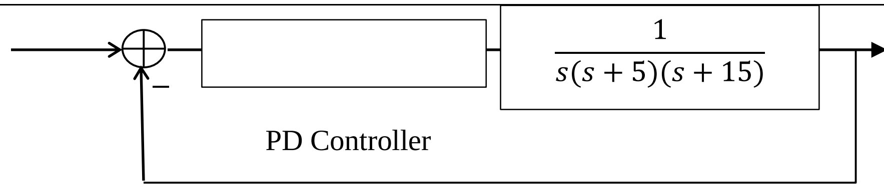
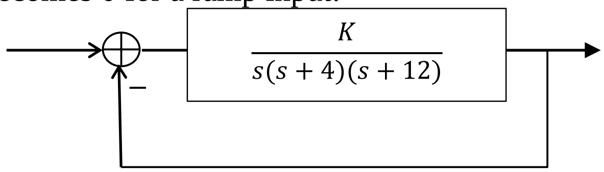
<tr>
<td>Conclusion about whether or not the design specifications are satisfied</td>
<td></td>
</tr>
<tr>
<td>Matlab code to generate the plot above</td>
<td></td>
</tr>
</table>

Problem 2	The following system operates with a dominant-pole damping ratio of 0.707. Design a **PD** controller in the form of $K(s+z_c)$ so that the settling time is reduced by a factor of 2. 
The PD-Compensated System	
Desired Pole Locations	$P_{\text{desired}} =$
Angle contributed by the PD zero	$\theta =$
Compute z_c via geometry	$z_c =$
The controller gain	$K =$
Plot the step responses of the original and the PD-compensated systems together	
Conclusion about whether or not the design specifications are satisfied	
Matlab code that generates the plot above	

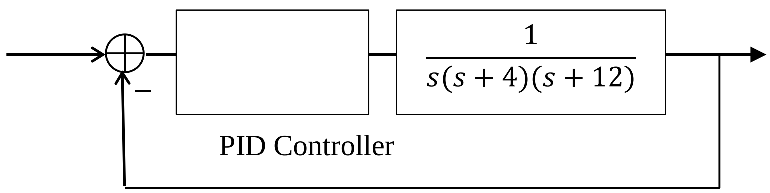
Problem 3	Design a **PD** controller for the system shown below to reduce the settling time by a factor of 4 while continuing to operate with 20% overshoot. 
The PD-Compensated System	
Desired Pole Locations	$P_{\text{desired}} =$
Angle contributed by the PD zero	$\theta =$
Compute z_c via geometry	$z_c =$
The controller gain	$K =$
Plot the step responses of the original and the PD-compensated systems together	
Conclusion about whether or not the design specifications are satisfied	
Matlab code that generates the plot above	

Problem 4: Given the following system that operates at 20% overshoot, design a **PID** controller that satisfies the following design specifications:

- The peak time can be reduced to be two-thirds without significantly affecting the $\%OS$
- The steady-state error becomes 0 for a ramp input.



Analysis of the original system to determine the desired pole locations		
1	Plot the root locus and find the value of K such that the original system operates at the specified %OS	
2	The closed-loop transfer function of the original system	
3	Can the original system have a valid 2nd-order approximation?	
4	The dominant poles of the original system	Pdominant =
5	The desired poles of the PD-compensated system	Pdesired =
Design the PD controller in the form of $K(s+z_c)$		
6	Compute the angle contributed by the introduced PD-zero	$\theta =$
7	Compute z_c using geometry	$z_c =$
8	Compute the controller gain	$K =$
9	The designed PD-controller is	$K(s+z_c) =$
10	Plot the step responses of the original and the PD-compensated systems. Are the design specifications satisfied for the transient?	
Design a PI controller in the form of $\frac{K(s+0.06)}{s}$		
11	Plot the root locus and find the value of K such that the PID-compensated system operates at the specified %OS	$K =$
12	The closed-loop transfer function of the PID-compensated system	
13	Does the PID-compensated system have a valid 2nd-order approximation?	

14	Validate your design by plotting the step responses of all three systems (the original, the PD-compensated, and the PID-compensated) in one figure. Are the design specifications satisfied for the transient?	
15	Is the design specification satisfied for the steady-state? How can you show it?	
16	Referring to the following structure, what is your designed PID controller? 	$K(s) =$