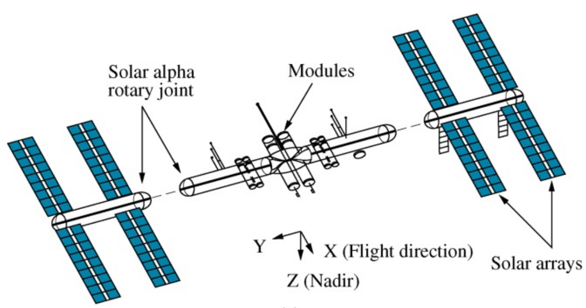
Studio #6: Steady-State Error

The objective of this studio is to reinforce recently learnt concepts in the class on steady-state error calculations.

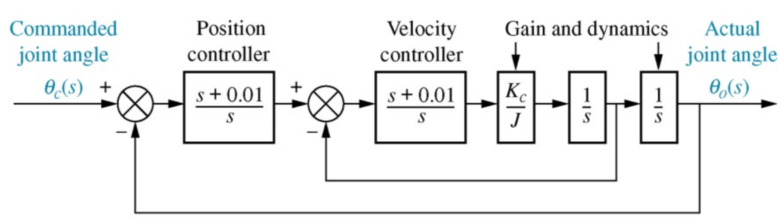
The table below, taken from the textbook, summarizes steady-state errors for unity feedback systems.

Input	Steady-state error formula	Type 0 Static error constant	Type 0 Error	Type 1 Static error constant	Type 1 Error	Type 2 Static error constant	Type 2 Error
Step, $u(t)$	$\frac{1}{1+K_p}$	$K_p = \text{Constant}$	$\frac{1}{1+K_p}$	$K_p = \infty$	0	$K_p = \infty$	0
Ramp, $tu(t)$	$\frac{1}{K_v}$	$K_v = 0$	∞	$K_v = \text{Constant}$	$\frac{1}{K_v}$	$K_v = \infty$	0
Parabola, $\frac{1}{2}t^2u(t)$	$\frac{1}{K_a}$	$K_a = 0$	∞	$K_a = 0$	∞	$K_a = \text{Constant}$	$\frac{1}{K_a}$

Example 1 A space station shown below in (a) will keep its solar arrays facing the sun using a solar tracking control system. The simplified block diagram in (b) represents the solar tracking control system that is used to rotate the solar arrays.



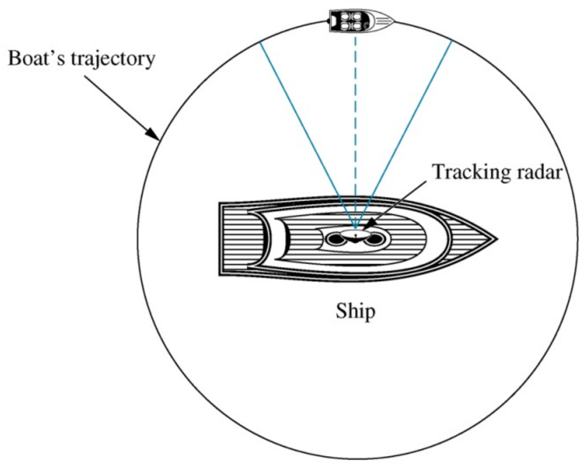
(a)



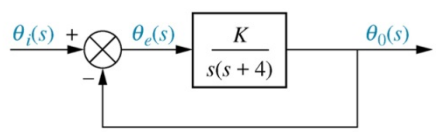
(b)

(A) What is the steady-state error for step commands? Why?
(B) What is the steady-state error for ramp commands? Why?
(C) What is the steady-state error for parabolic commands? Why?

2) A boat is circling a ship that is using a tracking radar. The speed of the boat is 20 knots, and it is circling the ship at a distance of 1 nautical mile, as shown in (a) below. A simplified model of the system is shown in (b). Find the value of K so that the boat is kept in the center of the radar beam with no more than 0.1-degree error.



(*a*)



(*b*)

Exercises

Each student shall complete the exercises below and get their work checked off by the studio instructor.

For Remote students and students who do not finish within studio session:

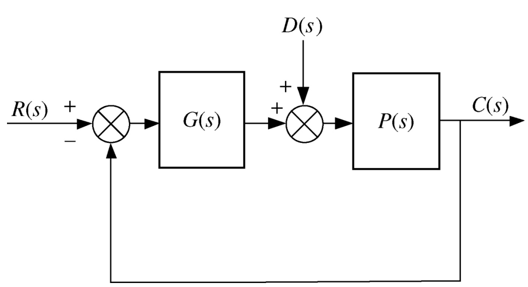
Compile the answers and outputs of Exercises 1 and 2 as well as your Matlab code in a word file and name it LastNameFirstNameStudio6.docx. Upload your file to Canvas under the Studio06 link.

Exercise 1 Develop a Simulink model or a Matlab script to model the solar tracking control system in Example 1 above. Let Kc/J=0.8. Use your Simulink model or Matlab script to verify the steady-state errors that were obtained analytically in Example 1 above for unit step, unit ramp and unit parabola inputs.

Hint: you will find the following Matlab functions useful:

```
G=tf(num,den) % constructs model for transfer function from num/den
T=feedback(G,1) % calculates equiv sys from a unity, negative feedback sys
lsim(T,input,t) % calculates the sys response for the given input & time
```

Exercise 2 In the figure below, let $G(s) = 5$ and $P(s) = \frac{7}{s+2}$.



(A) Calculate the steady-state error due to a command input R(s)=3/s and D(s)=0. Then, construct a Simulink model or write a Matlab script to model the system above and verify your calculated answer.

(B) Calculate the steady-state error due to a command input R(s)=0 and D(s)=-1/s. Then, verify your answer using your Simulink model or Matlab script.

(C) Now, calculate the steady-state error due to a command input R(s)=3/s and D(s)=-1/s simultaneously applied to the system. Then, verify your answer using your Simulink model or Matlab script.