Objective:
1. To design a Feedback Regulator for the Motomatic
2. To design a Feedback Controller for the Motomatic

Pre-Lab: (Counts as HW#13 - Due Wednesday, Oct. 14). Recall the objective of the first two experiments was to obtain a model for the Motomatic. While we obtained three different models (two from Lab 1 and one from Lab 2), the model which best describes our system dynamics with unity feedback is:

\[
\dot{x} = \begin{bmatrix}
0 & 3.1 \\
-68.0164 & -5.27
\end{bmatrix} x + \begin{bmatrix}
0 \\
68.0164
\end{bmatrix} V_{in}
\]

where \(x=[V_{out} \ V_{g}]^T\) (recall that \(V_{out}=K_p \theta_{out}\) and \(V_{g}=K_g \omega_m\)). If we eliminate the unity feedback loop and operate the Motomatic in open-loop (i.e., without feeding back the potentiometer voltage, \(-V_{out}\)) we obtain the following state variable model (can you show this?):

\[
\dot{x} = \begin{bmatrix}
0 & 3.1 \\
0 & -5.27
\end{bmatrix} x + \begin{bmatrix}
0 \\
68.0164
\end{bmatrix} V_{in}
\]

It is this model that we will use in Lab 3.

1 a) Design a feedback regulator such that the following specifications are met:
   1) \(V_{out}\) has no overshoot
   2) \(V_{out}\) settles to 2% of it's initial value within 0.3s

b) Simulate your regulator on Matlab using lsim* (or Simulink!!) given the initial state, \(x(0) = [10 \ 0]^T\)

c) If your design does not meet specifications, change your design until it does and explain why your initial design did not work (hint: recall the settling time measures how fast the decoupled modes go to zero!)

d) Use Matlab to make a plot of the decoupled modes versus time using the relationship that \(z_{decoupled}=P^{-1}x\). (hint: you can do this in Matlab via the statement: plot(t,inv(P)*x) where \(P\) is the matrix of eigenvectors of \((A-BK)\))

2 a) Now, design a controller to meet the following specs:
   1) \(V_{out}\) has no overshoot
   2) \(V_{out}\) settles within 0.3s
   3) \(V_{out}\) steady-state = 4 volts
   4) The steady-state error between \(V_{out}\) and 4 volts is about zero

   (Note: we are actually performing position control of the Motomatic D.C. servo! If \(V_{out}\) goes to 4 volts in steady-state, then \(\theta_{out}\) will go to \(V_{out}/K_p = 4/5.1394 = 0.778\) radians!)

b) Use Matlab (or Simulink!!) to simulate your controller. Make any adjustments needed to meet specs

c) Draw a block diagram of your controller with your model for the Motomatic

In Lab!!: (Due Monday, Oct. 19)
1. Implement your regulator (i.e., \(Nx=Nu=0\)) in Lab and obtain a zero-input response with \(x(0) = [10 \ 0]^T\). You can do this by turning the flywheel until 10 volts appears on the test meter then run the regulator with a step input of 0. Does the zero-input response agree with your Pre-Lab simulation?

2. Now set the initial conditions to zero and find the regulator step response. What is the steady-state error? Why is it so large?

3. Measure \(t_s\) and compare to the results of your Pre-Lab. If \(t_s\) does not meet specs, adjust your regulator design until it does!

4. Implement your controller design and obtain a step-response so that \(V_{out}\) goes to 4 volts (or \(\theta_{out}\) goes to 0.778 radians). Again, measure the steady-state error and compare to Pre-Lab results. Explain any discrepancies.

5. Although we designed our controller to follow a step (constant \(y_{ref}\), obtain a ramp response with slope of 0.5 (i.e., \(w(t)=0.5t(t)\)) for 2 seconds. What is the steady-state error?

*LSIM Simulation of continuous-time linear systems to arbitrary inputs.
LSIM(A,B,C,D,U,T) calculates and plots the time response of the system:
\[
dx/dt = Ax + Bu \\
y = Cx + Du
\]
to input time history U. Matrix U must have as many columns as there are inputs, U. Each row of U corresponds to a new

time point, and U must have LENGTH(T) rows.

[Y,X] = LSIM(A,B,C,D,U,T) also returns the state time history LSIM(A,B,C,D,U,T,X0) can be used if initial conditions
exist.