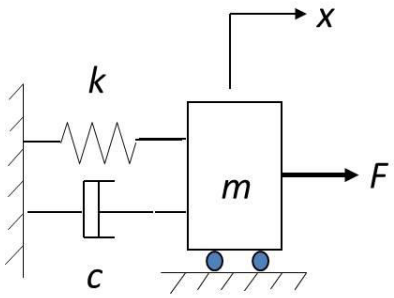
ECE327: LABORATORY EXERCISE 5:

Consider the following mass-spring-damper system.



The governing equation of this system is

$$m\ddot{x} + c\dot{x} + kx = F \xrightarrow{LT} \frac{X(s)}{F(s)} = \frac{1}{ms^2 + cs + k}.$$

Let $m = 1Kg$, $c = 10N \cdot s/m$, and $k = 20N/m$. The system is controlled by a PID (Proportional-Integral-Derivative) controller:

$$\frac{U(s)}{E(s)} = k_p + k_d s + k_i \frac{1}{s}$$

where k_p denotes the proportional gain, k_d denotes the derivative gain, and k_i denotes the integral gain. The goal of this exercise is to show how each of the terms k_p, k_d, and k_i, contributes to obtaining the common goals of:

- Fast rise time
- Minimal overshoot
- Zero steady-state error

A. Obtain the open loop response of the system and determine what needs to be improved.
B. For each of the following cases, find the closed-loop transfer function by utilizing the appropriate Control System Toolbox commands. Then find the step response of the system and comment on the above common goals.

(I) PROPORTIONAL CONTROL

$$\frac{X(s)}{F(s)} = \frac{k_p}{s^2 + 10s + (20 + k_p)}$$

Let $k_p = 300$. What will be the effect on the response if you increase / decrease the value of proportional gain?

(II) PROPORTIONAL-DERIVATIVE CONTROL

$$\frac{X(s)}{F(s)} = \frac{k_d s + k_p}{s^2 + (10 + k_d)s + (20 + k_p)}$$

Let $k_p = 300$ and $k_d = 10$. What will be the effect on the response if you increase / decrease the value of derivative gain?

(III) Proportional-Integral Control

$$\frac{X(s)}{F(s)} = \frac{k_p s + k_i}{s^3 + 10s^2 + (20 + k_p)s + k_i}$$

Let $k_p = 30$ and $k_i = 70$. What will be the effect on the response if you increase / decrease the value of integral gain?

(IV) Proportional-Integral-Derivative Control

$$\frac{X(s)}{F(s)} = \frac{k_d s^2 + k_p s + k_i}{s^3 + (10 + k_d)s^2 + (20 + k_p)s + k_i}$$

Let $k_p = 350$, $k_d = 50$, and $k_i = 300$. Having in mind the effect of each term on the controller, adjust the gains and comment on the response of the system.