# Lab 1: System Modeling in Maple

We are going to do some virtual experiments by simulating a mass-spring-damper system using Maple. This system is shown in Figure 1 below:



f(t)

Figure 1: A Mass-Spring-Damper System

We will use a mass $m=1 kg$ so the transfer function model is

$$\frac{X(s)}{F(s)}=\frac{1}{s^{2}+cs+k}$$

1. Manually derive the general transfer function for the system by hand.
2. Compare the effects of a unit response and unit impulse function to disturb the system:
	1. Using *m* = 1, *k* = 2, and *c* = 3 derive the time domain equations for both inputs and plot your results. Comment on the results.
	2. Using *m* = 1, *k* = 2, and *c* = 2 derive the time domain equations for both and plot your results. Comment on the results.
3. Compare and contrast on the system response to the two inputs. What effect does the damping coefficient play on the system? What effect would a damping coefficient of zero have on the system?

# Lab 2: System Modeling in MapleSim

We are going to do some virtual experiments by simulating a mass-spring-damper system using Maple and MapleSim. This system is shown in Figure 1 below:



f(t)

Figure : A Mass-Spring-Damper System

We will use a mass $m=1 kg$ so the transfer function model is

$$\frac{X(s)}{F(s)}=\frac{1}{s^{2}+cs+k}$$

1. Manually derive the general transfer function for the system by hand.
2. Construct the model in MapleSim and extract the equations for the system. Use a step signal with a height of 1 for the force input. Compare the results to your hand calculations.
3. Clearly, the original transfer function model is parameterized by *c* and *k*. Can you convert it into a transfer function model that is parameterized by *ζ* (damping ratio) and *ωn* (natural frequency)? Analyze the relationship between *c, k* and *ζ, ωn­*. What is your opinion on how c and k affect the damping and natural frequency?
4. Suppose that we have the following spring and damping values:

|  |  |
| --- | --- |
| *k* = 1, 4, 9, 16, 25 $\frac{N}{m}$ | *c* = 0.5, 1.0, 1.5, 2.0, 2.5 $\frac{N s}{m}$ |

1. Using a spring constant of *k* = 1 obtain the results of a 10 second simulation of a unit-step response *x(t)* to *f(t)* for dampers with *c* = 0.5, 1.0, 1.5, 2.0, 2.5 $\frac{N s}{m}$, respectively.
2. Using a damping ratio of *c* =1 obtain the results of a 10 second simulation of a unit-step response *x(t)* to *f(t)* for springs with *k* = 1, 4, 9, 16, 25 $\frac{N}{m}$, respectively.
3. Analyze the plots obtained in step 2.
4. If you are required to improve the system’s damping ratio or natural frequency using springs and dampers, discuss possible solutions.

# Lab 3: Control design in Maple and MapleSim

We are going to do some virtual experiments by simulating a mass-spring-damper system using Maple and MapleSim. This system is shown in the figure:



f(t)

Figure : A Mass-Spring-Damper System

For our model, we will use $m=1 kg$, $c=3 \frac{N s}{m}$, and $k=2\frac{N}{m}$ so the transfer function model is

$$\frac{X(s)}{F(s)}=\frac{1}{s^{2}+3s+2}$$

Using the provided MapleSim model, develop a P, PI, and PID controller to dampen out the effect of a sinusoidal disturbance applied to the mass.

1. Open the MapleSim model and load the attachment Project > Attachments > Documents > ControlDesing.mw
2. In Maple, select the subsystem msd2 and press “Load Selected Subsystem.” The model information will be loaded into the template.
3. Press “Toggle Symbolic” to keep the equations in their symbolic form. Press “Reassign Equations” to update the template.
4. Execute the commands sys := DiffEquation(DAEs, F(t), x(t)) and tf := TransferFunction(sys). These commands take the differential equation of the system and convert it to transfer function.
5. Select P from the controller type dropdown. The closed loop transfer function is generated.
6. Execute the commands TFClosedloopParam := eval(TFclosedloop, {c = 3, kspr = 2, m = 1}) and response := 1/s\*TFClosedloopParam. These commands assign the desired parameters to the equation and apply a unit step to the input.
7. Copy and paste the transfer function created above into the window.
8. Move the sliders for the controller gains and explore the effects on the system response. How do the gains effect the system?
9. When you have tuned your system accordingly, export your gains back to the model by pressing “Return to MapleSim.”
10. Return to the MapleSim environment and run your simulation and compare the controlled response to the non-controlled model.
11. Repeat steps 4-9 for PI and PID controllers.