Lab 2 - Translational & Rotational Systems

Overview

In this lab you will build models of both a translational and rotational dynamic system using both standard Simulink and the Simscape toolbox.

Resources Required:
MATLAB
Simulink
Simscape

Description of the System

The following two tables describe the two systems that will be modeled in this lab. Both provide a simple Free Body Diagram along with defined properties.

Translational System

Property	Variable	Value	Units
Mass	m	1	kg
Spring constant	k	1.3	N/m
Damping ratio	b	1.25	$N/(m/s)$

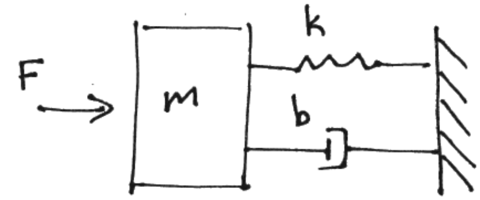

Table 1: Translational System Description

Rotational System

Property	Variable	Value	Units
Moment of inertia	j	1795	$g \cdot cm^2$
Spring constant	k	0.01	$N \cdot \mathrm{m/rad}$
Damping ratio	b	0.001	$N \cdot \mathrm{m/(rad/s)}$

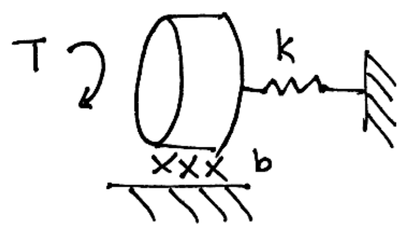

Table 2: Rotational System Description

Task 1: Modeling a Translational System

For this task we will model the translational system described from table 1 using a standard control systems approach and Simulink. You will then model the same system using the Simscape toolbox.

1a: Model Translational System using Simulink

Create a block diagram of the translational system model within Simulink using the basic elements found within a common control system block diagram.

1. Start by creating the fundamental block diagram for the system. It will result in looking like the diagram shown in figure 1. Highlight the whole system and click on the 3 dots, select "Auto-route Lines". Capture a screenshot after completion and include it in your report.

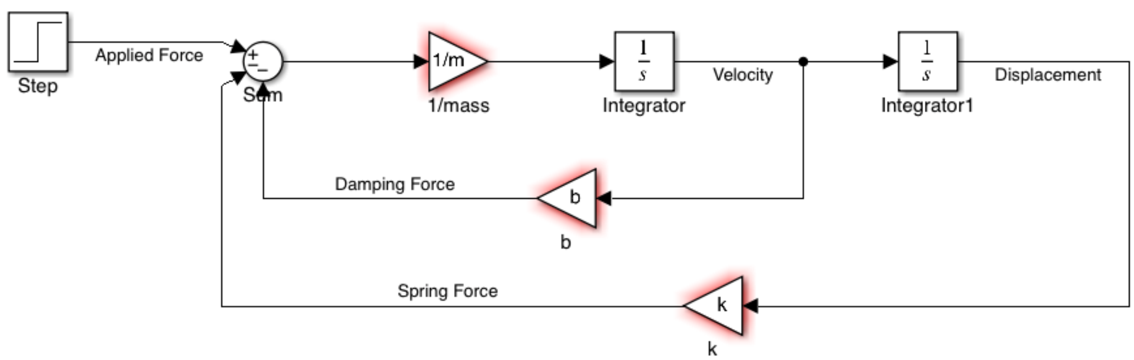

Figure 1: Translational System Fundamental Block Diagram

NOTE: Blocks with undefined variables within Simulink will be indicated with a red shadow behind the block. Since we have not yet defined the variables for the gain blocks, they are indicated as such. We will define them in the following steps.

NOTE: The current block diagram does not include any way of observing the behavior of the system. It only has the fundamental blocks to create the system with input and closed loop feedback. You will add a scope in the next step to observe its behavior.

2. In order to view the simulation of the model we will need to add a scope. Add a bus creator and scope to sample the system.
3. Update the gain blocks and step function as follows:
    a. Gains: 1/m, b, and k in the appropriate gain blocks (as shown in the diagram)
4. Define the variables for the gains as follows:
    a. Final Step Value = 2
    b. m = 1
    c. k = 1.3
    d. b = 1.25

NOTE: This can be done either by defining them in the base workspace simply by typing them in the command window on the main MATLAB interface, or by entering them into the model workspace accessible through the Simulink interface.
Then update the model (Navigate to “Modelling” --- “Update Model”)

For quick reference, you can access the model workspace by doing the following within Simulink.

1. At the top of the Simulink ribbon click on “MODELING”
2. Click the drop-down arrow above the “DESIGN” section within the top ribbon
3. Click “Model Workspace” under the REPOSITORIES section of the drop-down. The “Model Explorer” window will then appear.
4. Click “Model Workspace” in the “Model Hierarchy” panel on the left side of the interface.
5. Here you can add or define/re-define a variable. To add a variable, click on the “Add” button at the top of the page and then click “MATLAB Variable” or use the hotkey “ctrl+m”.

5. Update the model by using the “ctrl +d” hotkey. (On a mac, this is the “cmd+d” hotkey.) You will notice the red shadows around the gains are no longer present, indicating the variables are now defined. (Navigate to “Modelling” --- “Update Model”)
6. The final block diagram of the system with a scope for observation will result in looking like the diagram shown in figure 2.

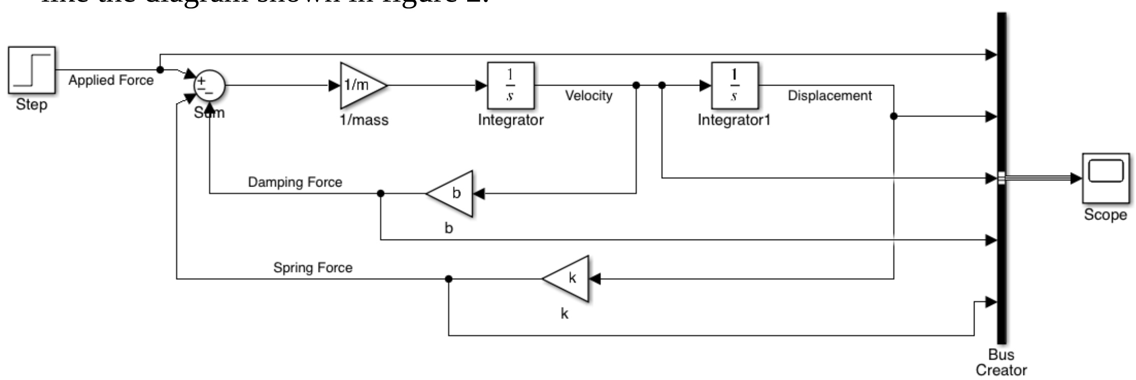

Figure 2: Translational System Block Diagram with Scope

7. Format and save the final block diagram and plot appropriately and include them in your report.

To show completion of this task, save your formatted scope plot and show the TA.

1b: Model Translational System using Simscape

Now rebuild the same model using the Simscape toolbox. If you cant find Simscape, use the command "ssc_new" in MATLAB command window. Figure 3 shows the final block diagram.

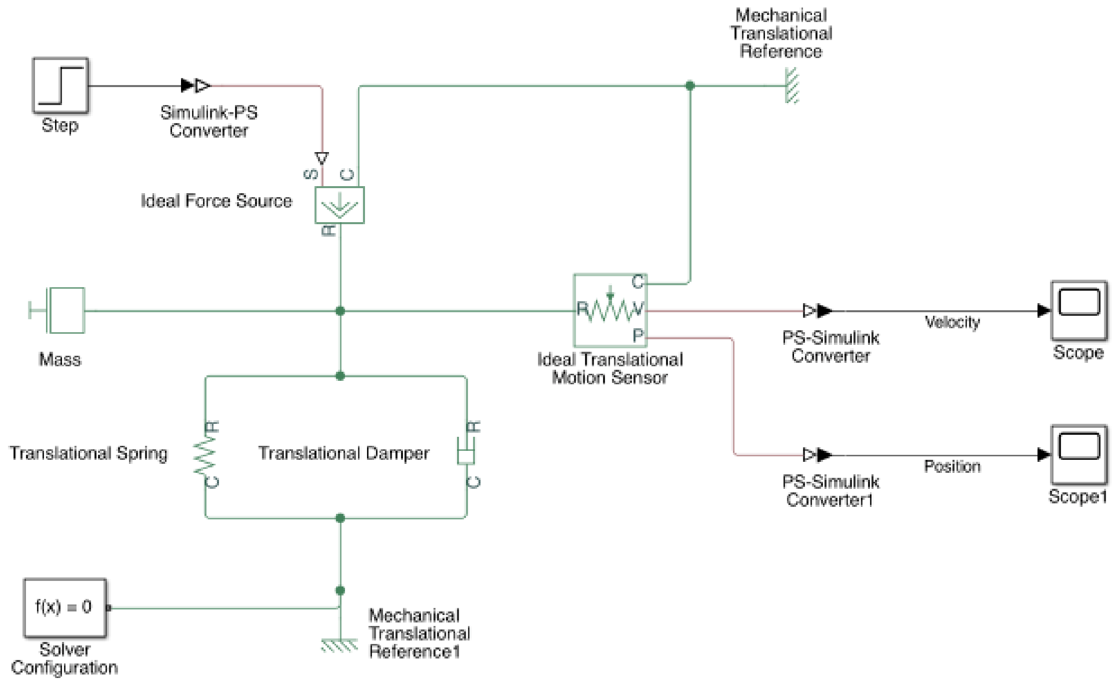

Figure 3: Translational System using Simscape

1. Update the appropriate blocks to define the system parameters. They will be the same values we used in task 1.
- Mass = 1 kg
- Spring Rate = 1.3 N/m
- Damping Coefficient = 1.25 N/(m/s)
- Final Step Value = 2 N

2. Navigate to the "Configuration Parameters" window by clicking on the "Modeling" tab at the top of the Simulink ribbon, then clicking the "Model Settings" button within the ribbon.
3. In the "Configuration Parameters" window, be sure you are on the "Solver" tab from the left side pane, then change the solver to "ode23t (mod.stiff/Trapesoidal)". Save your changes then run the simulation.
4. Format and save the final block diagram, and the velocity and position plots appropriately and include them in your report. (Be sure to include a y-axis label with units.)

To show completion of this task, save your formatted scope plot and show the TA.

Task 2: Modeling a Rotational System

For task 2, we will be modeling the translational system we defined in the lab overview using Simscape. The diagram will look like it is shown in figure 4.

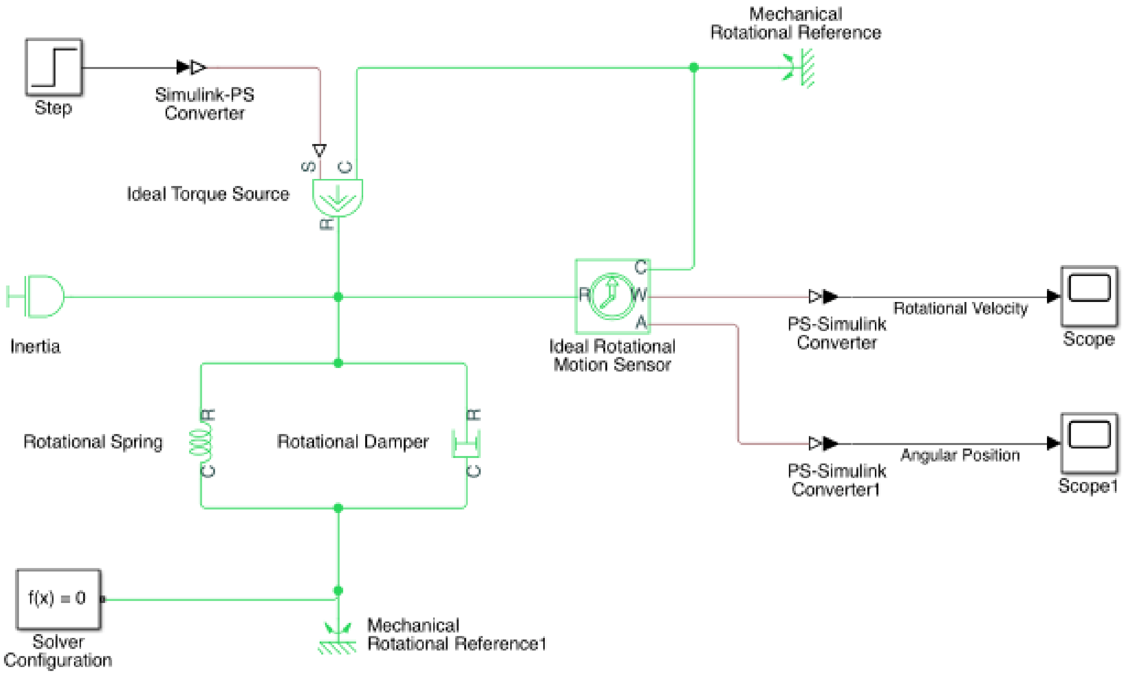

Figure 4: Rotational System using Simscape

1. Update the appropriate blocks to define the system parameters.

- Final Step Value = 0.01 $\mathrm{N \cdot m}$
- Spring Rate = 0.01 $\mathrm{N \cdot m/rad}$
- Damping Coefficient = 0.001 $\mathrm{N \cdot m/(rad/s)}$
- Inertia = 1795 $\mathrm{g \cdot cm^2}$ (This is about the inertia of a frozen can of soda. Note that "moment of inertia" would be a more appropriate description.)

2. Navigate to the "Configuration Parameters" window, and change the solver to "ode23t (mod.stiff/Trapesoidal)". Save your changes then run the simulation.
3. Format and save the final block diagram, and the velocity and position plots appropriately and include them in your report. (Be sure to include a y-axis label with units.)

NOTE: You should now have a total of 4 block diagrams and 5 plots to include in your report. Be sure they look appropriate.

Post-Lab Questions

From the 5 signals plot from task 1a:

1. Why do spring force and displacement have similar curves? Why do velocity and damping force have similar curves?
2. At the end of the simulation, why does the velocity return to zero but the displacement does not return to zero?
3. How can you manipulate the damping force to increase the number of oscillations in velocity? Verify by trial.

From the velocity plot from task 1b:

4. About how many seconds does it take to reach peak velocity? Increase the mass from 1kg 5kg. Now, about how many seconds does it take to reach peak velocity?

From the position plot from task 1b (with original 1kg mass):

5. What is the final resting displacement (approximate to 1 decimal place)? What are the units?
6. After 10 seconds (end of the simulation) there is still a tiny movement, so your approximation in the previous question is not exact. Calculate the exact final resting displacement to 4 decimal places. Hint: when the system comes to rest, the equation to describe it is just a balance of the spring force against the input force. Show your calculation including units for each term.