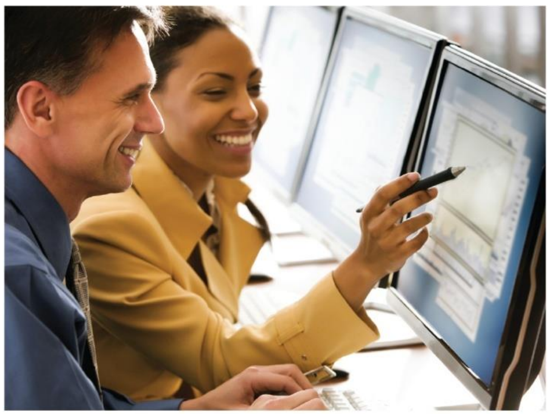
MathWorks | Training Services

Exercises: Building Mechanical Assemblies – Part 2

Physical Modeling for Formula Student



MathWorks | Training Services

Four-Bar Linkage Dynamics

Try

```
>> fourbarDyn_start
```

Task: Add initial conditions, internal mechanics and force actuation to the four-bar linkage assembly.

Steps: Modify the model `fourbarDyn_start` to add dynamics to the four-bar linkage model.

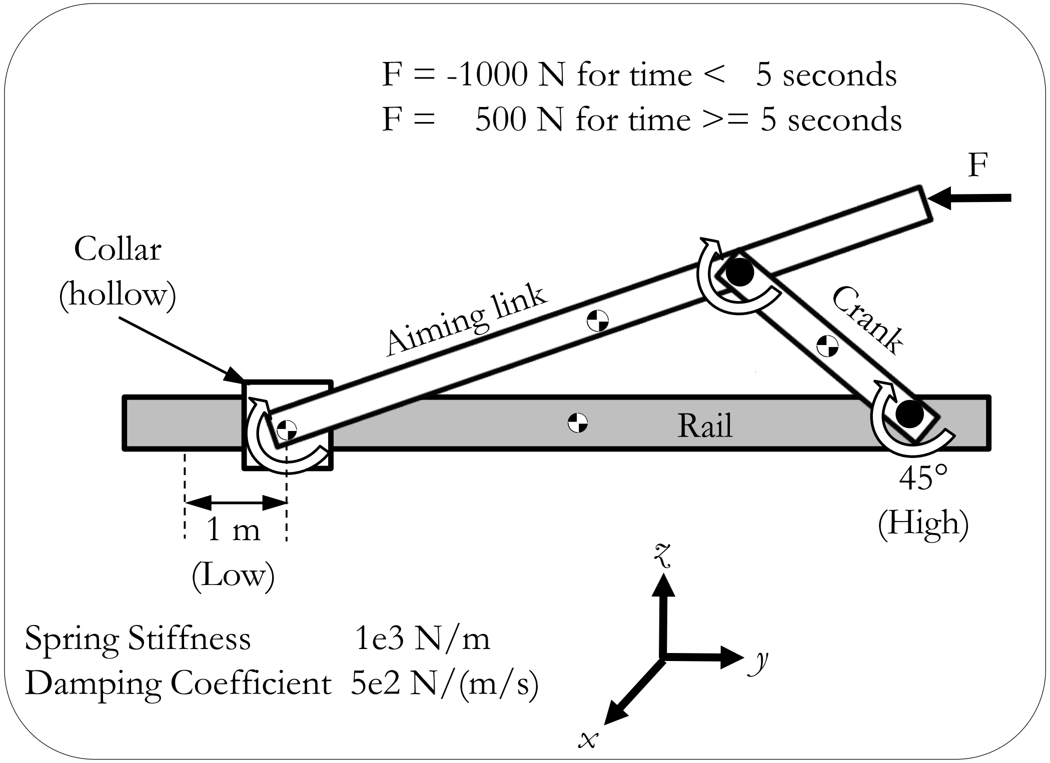
1. **Specify the initial configuration of the assembly.**
   Use State Targets to change the initial positions of the joints. Specify `High Priority` position target for Revolute Joint to be `45°`.

   (Bonus) Try to over-constrain your system and change the priorities to introduce conflicts. For example, specify a `High Priority` position target of `1 m` for the Prismatic Joint block. Update the model and open the Simscape Variable Viewer to see if all high-priority targets are satisfied. Change the priority of this target to `Low`. Update the model and use the Simscape Variable Viewer to see if all `High Priority` targets are now satisfied.

2. **Specify internal mechanics for the Prismatic Joint block.**
   Set the **Spring Stiffness** to `1e3 N/m` and the **Damping Coefficient** to `2e2 N/(m/s)`. Compare the simulation results.

3. **Add external force at the tip of the aiming link.**
   Use an External Force and Torque block to apply a step force along the *y*-axis of the world frame at the tip of Aiming Link subsystem (available as the Force Frame) as follows:

   F = -1000 N   if t < 5 seconds
   F = 500 N   if t ≥ 5 seconds

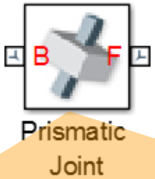


Solution: Four-Bar Linkage Dynamics

Try

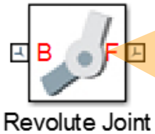
```
>> fourbarDyn_solution
```

1. Initial Conditions



Internal Mechanics		
Equilibrium Position	0	m
Spring Stiffness	1e3	N/m
Damping Coefficient	2e2	N/(m/s)

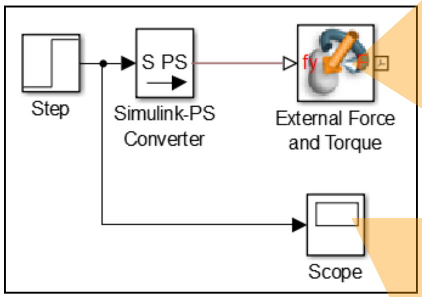
2. Internal Mechanics



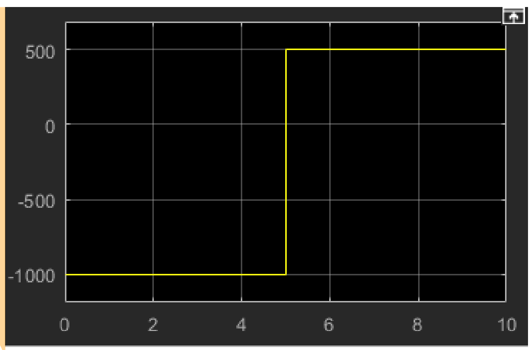
State Targets		
Specify Position Target	☑	
Priority	High (desired)	
Value	45	deg

State Targets		
Specify Position Target	☑	
Priority	Low (approximate)	
Value	1	m

3. Force Actuation



Actuation	
Force	
Force (X)	☐
Force (Y)	☑
Force (Z)	☐
Force	☐
Force Resolution Frame	World



Hydraulic Suspension

Try

```
>> hydSuspStart
```

Task: Connect a hydraulic mechanism to the shock absorber in a suspension model.

Steps:

1. Open the model `hydSuspStart` and navigate to the `Shock Absorber` subsystem.

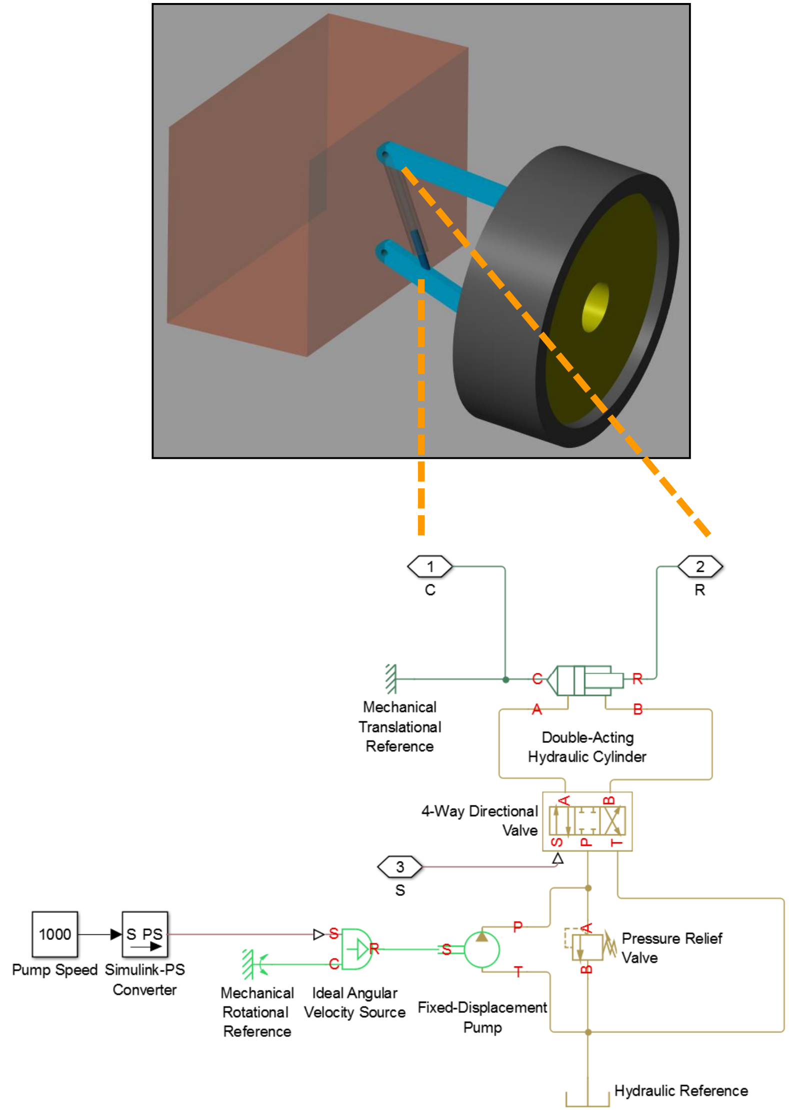
2. The `Hydraulic Actuator` subsystem contains an S port, which is the position of a hydraulic valve spool that controls the flow to the hydraulic cylinder. There are also two unconnected ports R and C, which correspond to Simscape™ mechanical translational ports at either end of the hydraulic cylinder. To connect these ports to the Prismatic Joint block,

   a. Enable force actuation and velocity sensing in the Prismatic Joint block.

   b. Drag a Translational Simscape Intf block from the `MS2G_SS_Intf_Lib.slx` library provided. This block contains Simscape sensor and source blocks to interface to SimMechanics using physical signals.

3. Simulate the model and analyze the results.

   Hint The `Wheel Subsystem` contains an External Force and Torque block that applies a step force input after 5 seconds of simulation. How does this affect the system response?

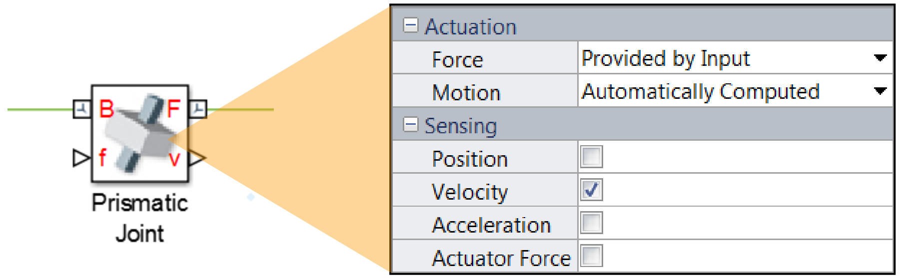


Solution: Hydraulic Suspension

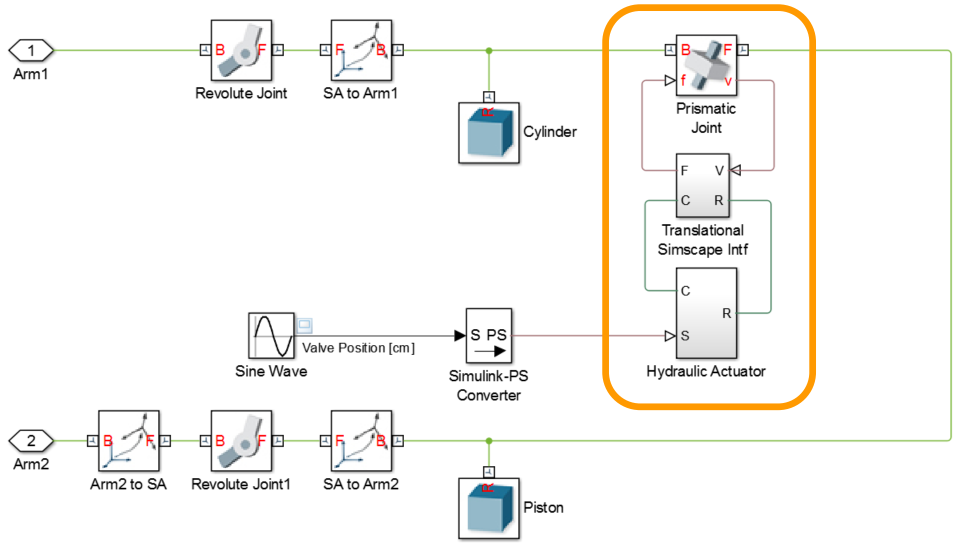
Try

```
>> hydSuspSoln
```

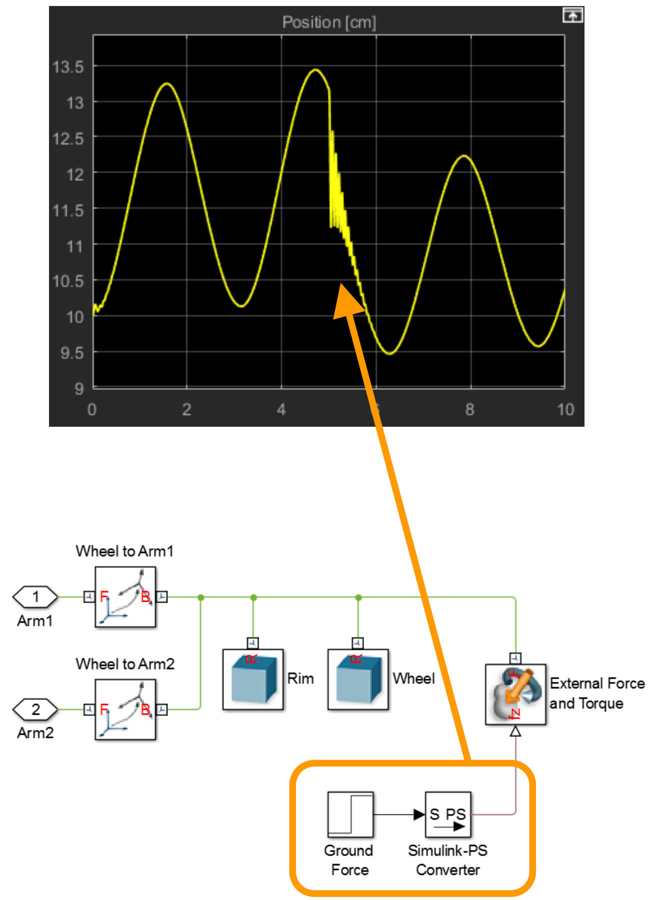
1. Configure the Prismatic Joint block to have force actuation and velocity sensing as shown below.



2. Add a Translational Simscape Intf block from the `MS2G_SS_Intf_Lib.slx` library provided. Connect it to the model as follows.



3. Simulate the model. Visualize the position of the Prismatic Joint block to verify the results. Note the sudden change in force after 5 seconds.



Hydraulic Suspension Control

Try

```
>> suspCtrlStart
```

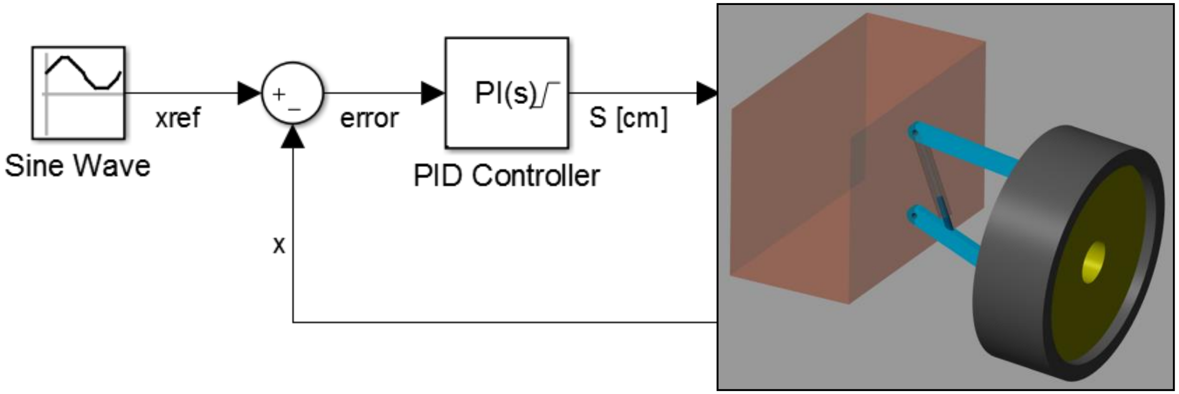
Task: Add a position controller to the hydraulic suspension model.

Steps:

1. Open the model `suspCtrlStart` and navigate to the `Shock Absorber` subsystem.
2. The subsystem contains a signal `xref`, which corresponds to the reference piston position in centimeters (`cm`). Build the closed-loop control architecture shown in the diagram. To do this,
    a. Add position sensing to the Prismatic Joint block. Ensure that the signal is converted to the correct unit (cm).
    b. Subtract the measured position `x` from the reference position `xref` to calculate the `error` signal.
    c. Add a PID Controller block from the **Simulink → Continuous** library. Set its parameters as shown on the right.
    d. Ensure the controller output signal `S`, which is the valve spool displacement, is converted to the correct unit (`cm`) before being applied to the hydraulic system.
3. Simulate the model and visualize the actual vs. measured position, as well as the control input `S`, in centimeters.

PI Controller Parameters:

Proportional Gain (P):	1
Integral Gain (I):	10
Saturation Limits:	+/- 5 cm



Solution: Hydraulic Suspension Control

Try

```
>> suspCtrlSoln
```

The solution model and simulation output looks as shown below.