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Kinematics

Joints

There are many joints available in Kinematics. Each joint has degrees of freedom and commands associated with it. A good understanding of these will make performing kinematics much easier. The table below gives an overview of the joints. Some of the joints can be created using axis systems but that will be discussed later.

Joint	Degrees of Freedom	Commands Available
Revolute	1 Rotation	Angle
Prismatic	1 Translation	Length
Cylindrical	1 Rotation 1 Translation	Angle and/or Length
Screw	1 Rotation or 1 Translation	Angle or Length
Spherical	3 Rotations	None
Planar	1 Rotation 2 Translations	None
Rigid	None	None
Point Curve	3 Rotations 1 Translation	Length
Slide Curve	2 Rotations 1 Translation	None
Roll Curve	1 Rotation 1 Translation	Length
Point Surface	3 Rotations 2 Translations	None
Universal	1 Rotation	None
CV	None	None
Gear	1 Rotation	Angle
Rack	1 Rotation or 1 Translation	Angle or Length
Cable	1 Translation	Length

Revolute - Null Offset

The revolute option allows you to define a joint that represents a rotation. This is useful when you need an object to turn about another object.

Open the Revolute Joint document located in the *Revolute* directory. You should see a base with three rings.
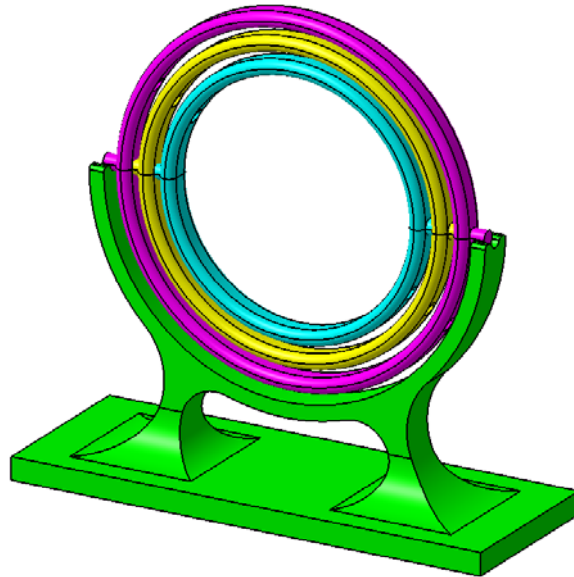
Select the Revolute Joint icon. The *Joint Creation : Revolute* window appears.
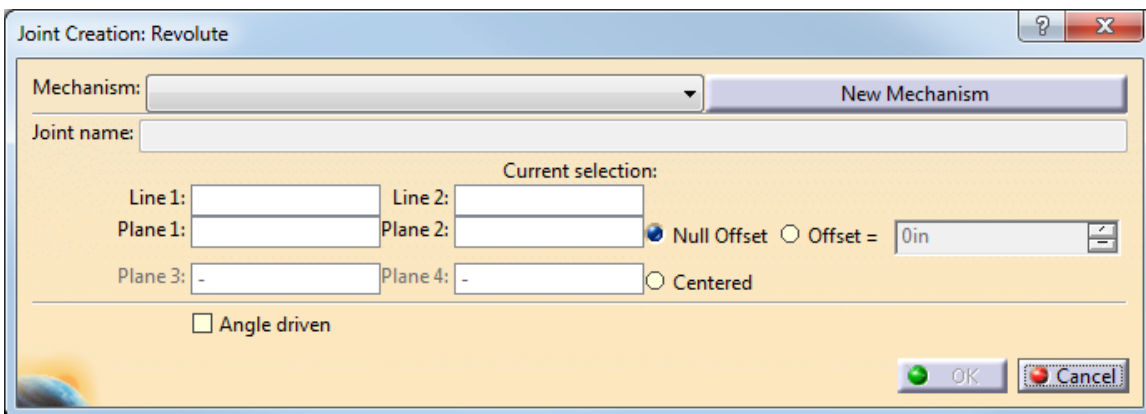
Mechanism	Specifies the mechanism for the joint to belong to, you have the option of defining a *New Mechanism*
Joint name	Specifies a name for the joint
Line 1,2	Defines the two lines that should line up and the mechanism should rotate around
Plane1,2	Defines the two planes that should line up, you have the option of defining an *Offset* value if they do not line up

Plane 3,4   Defines two additional planes in order to make the two objects *Centered*

Angle driven   Allows you to attach an angle command

Select the *New Mechanism* button. The *Mechanism Creation* window appears. A mechanism needs to exist before a joint can be made. You can do this by using this option within the joint or by selecting pull down menu *Insert, New Mechanism*.
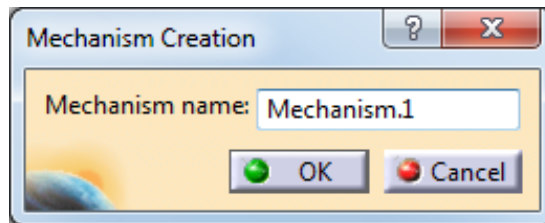
Key Gyro for the *Mechanism name* and select *OK*. You are going to use the default name for the joint.

Select the center line of the cylinder on the outside ring and the center line of the cutout on the base as shown below. This defines the center of rotation and aligns the two lines.
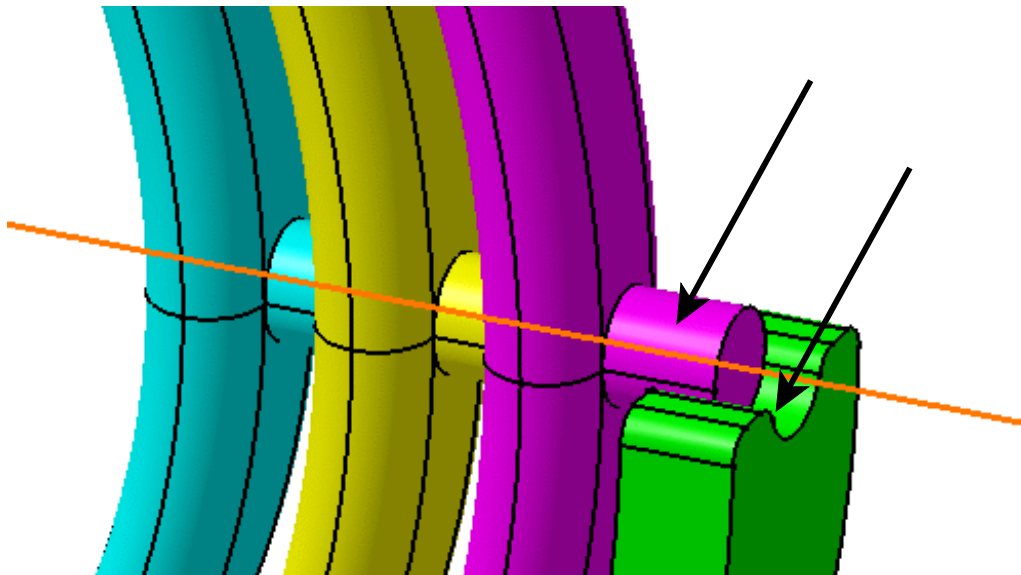
Select the *zx plane* in both parts. This defines the location of each object by aligning the two planes. You will probably have to expand the branches of the *Base* and *1ˢᵗ Ring* in order to select the planes.

Select *OK*. The joint is created. A *Mechanisms* branch appears in your specification tree.

Expand the branch in order to see all the elements below. Notice that the mechanism has one degree of freedom. Remember it was stated that an assembly must have at least one degree of freedom in order to be used in kinematics. However, in order to simulate the mechanism you must have commands assigned to it, giving it 0 degrees of freedom. In addition you must have a fixed part defined.
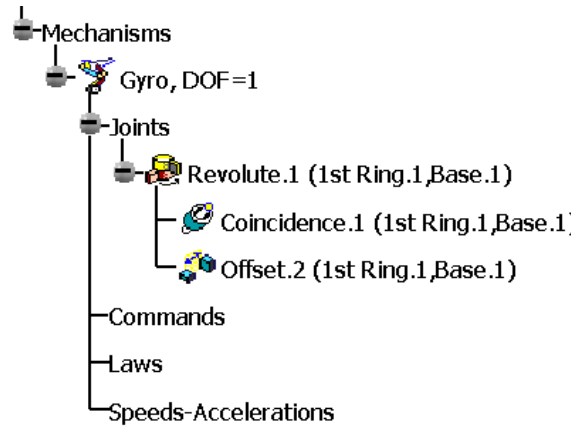
Select the Fixed Part icon. The *New Fixed Part* window appears. You need to specify which part is fixed. If you had more than one mechanism than you would need to select the appropriate one from the drop down list in order to define the fixed part for that mechanism.
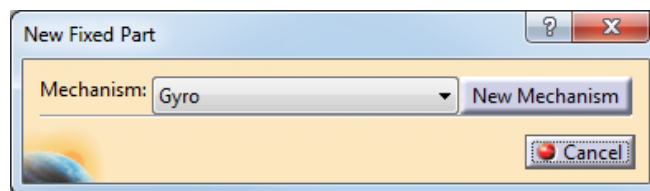
Select the Base. You can select it from the graphical work area or from the specification tree. A *Fix Part* branch appears under the mechanism in the specification tree. Since you did not specify a command when creating the joint you will need to go back and modify the joint to include a command.

Double select on the *Revolute* joint in the specification tree. The *Joint Edition : Revolute* window appears.
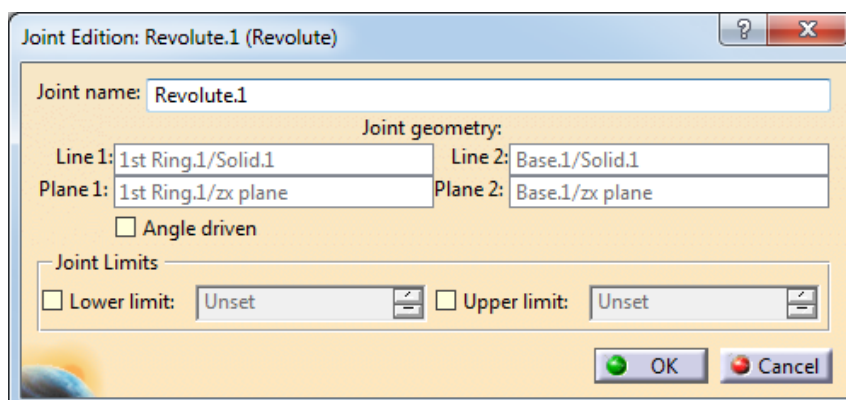
Joint Limits   Sets limits for the range of motion if you turn on the *Angle driven* option

Select the *Angle driven* option and select *OK*. This will add an angle command to the joint. An *Information* window appears telling you that the mechanism can be simulated.
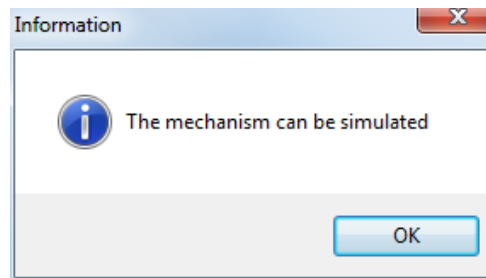
Select *OK*. Notice that the mechanism has 0 degrees of freedom and there is command in the *Commands* branch under the mechanism. You will now simulate the joint.

Select the Simulation with Commands icon. The *Kinematics Simulation* window appears.

Select the *More>>* button. The window shows more options. These options will be covered in detail later in the course.
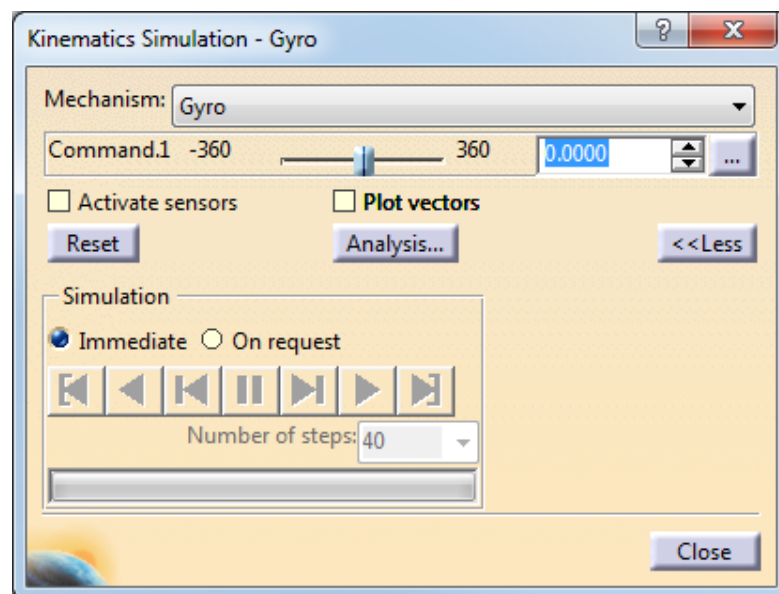
Turn on the *On request* option and drag the slider for *Command.1* to the right to *360*. This will tell it to simulate one revolution.

Change the *Number of steps* to be 40 and select the Play Forward icon. The outer ring rotates around one complete revolution.

Select the *Reset* button and select *Close*. This defines one joint. You will continue to define revolute joints in order for the complete assembly to be defined.

Select the Revolute Joint icon again. The *Joint Creation : Revolute* window appears. This time the mechanism is already specified.

Select the center line of the cylinder on the outside of the middle ring and then the center line of the hole of the outer ring as shown below. This defines the lines.
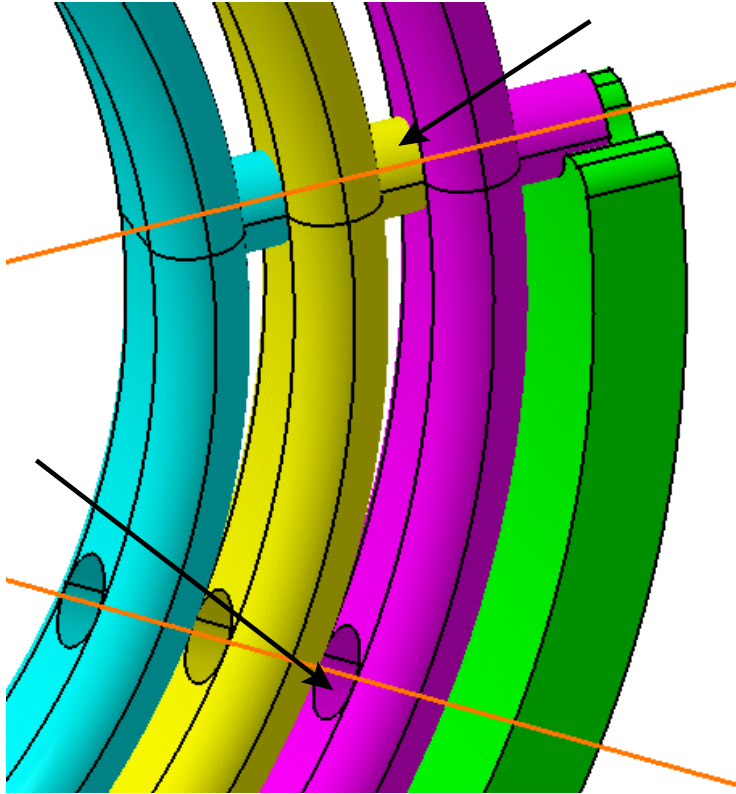
Select the *zx plane* in the *2ⁿᵈ Ring* and *Plane.1* from *Geometrical Set.1* in the *1ˢᵗ Ring*, turn on the *Angle driven* option and select *OK*. The middle ring moves to have the two lines line up. An *Information* window appears.

Select *OK*. The window closes.

Define the revolute joint between the inner ring and the middle ring and select *OK* when the *Information* window appears. You do this in the same manner as you did the second revolute joint. The inner ring should move to align with the hole in the 2ⁿᵈ Ring.

Select the Simulation with Commands icon again. The *Kinematics Simulation* window appears. This time there are three commands available to simulate.

Make sure the *On request* is turned on and drag the slider for all three commands to 360.

Change the *Number of steps* to *80* and select the Play Forward icon. The three rings rotate one full revolution each.

Select *Close*. The window closes. Your first kinematic mechanism has been defined.

Your final mechanism should appear similar to the one shown below.
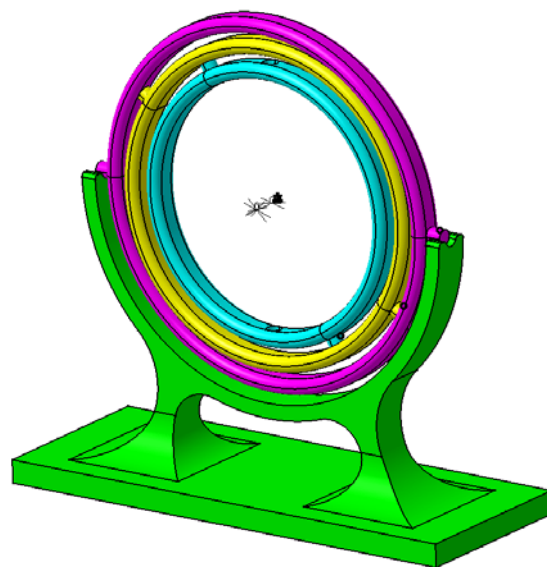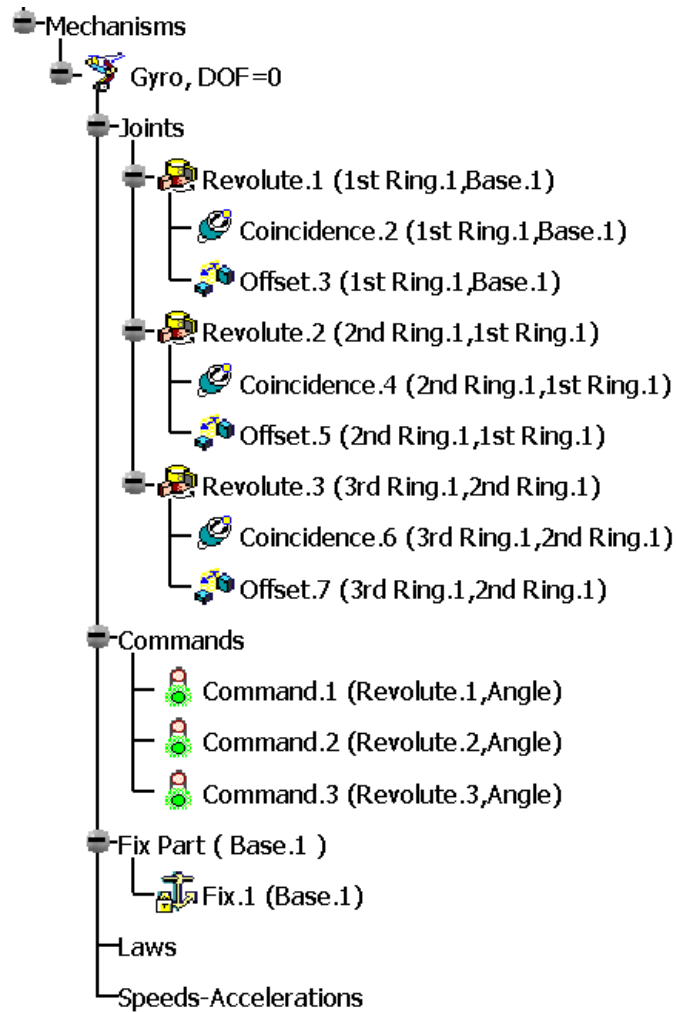
Save and close your document.

Assembly Constraints

There are many times that you created an assembly and constrained it within Assembly Design. Assembly constraints are not recognized in Kinematics, therefore you have to define joints. However, assembly constraints can be converted into joints.

Auto Create

Open the Assembly Constraints document located in the *Assembly Constraints* **directory.** You should see a linkage assembly with two pistons. All of the objects have been constrained and the assembly can move with respect to constraints within Assembly Design.
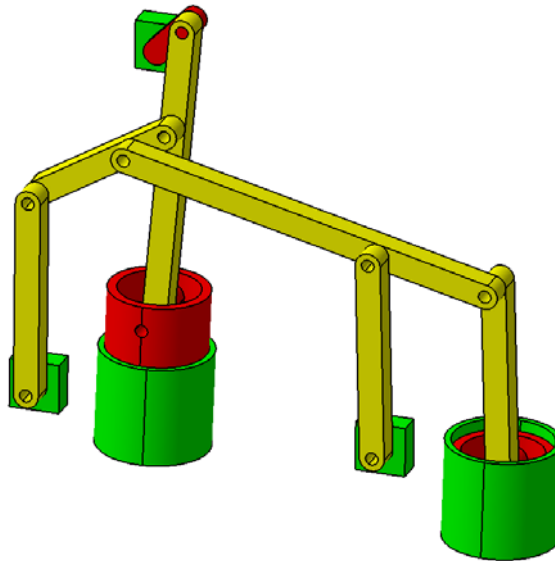
Select the Assembly Constraints Conversion icon. The *Assembly Constraints Conversion* window appears.
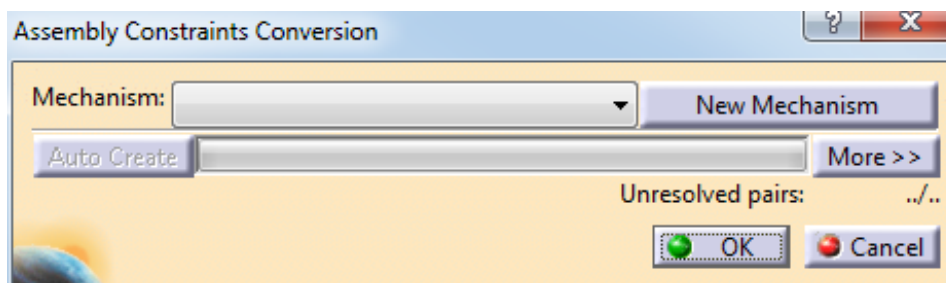
Mechanism	Allows you to choose an existing mechanism if one exists or you can create a *New Mechanism*
Auto Create	Enables CATIA to automatically create joints from the constraints
More>>	Expands the window to show additional options available to manually match constraints to joints

Select the *New Mechanism* button and create a mechanism called <u>Linkage</u>. The *Auto Create* button becomes available.

Select the *Auto Create* button. Joints are automatically defined based on the assembly constraints. There are 17 joints and no *Unresolved Pairs*.

Select *OK*. Notice that you still have 1 degree of freedom. You need to add a command to one of the joints.

Double select on *Revolute.4* from the specification tree. The *Joint Edition* window appears.

Select the *Angle driven* option and select *OK*. An *Information* window appears.

Select *OK*. The window closes.

Select the Simulation with Commands icon, select *On request*, drag the slider all the way to the right, change the *Number of steps* to 40 and select the Play Forward icon. The mechanism goes in motion. As you can see the conversion was very successful and you did not have to manually create any of the constraints.

Select *Close*. The window closes.

Your final mechanism should appear similar to the one shown below.
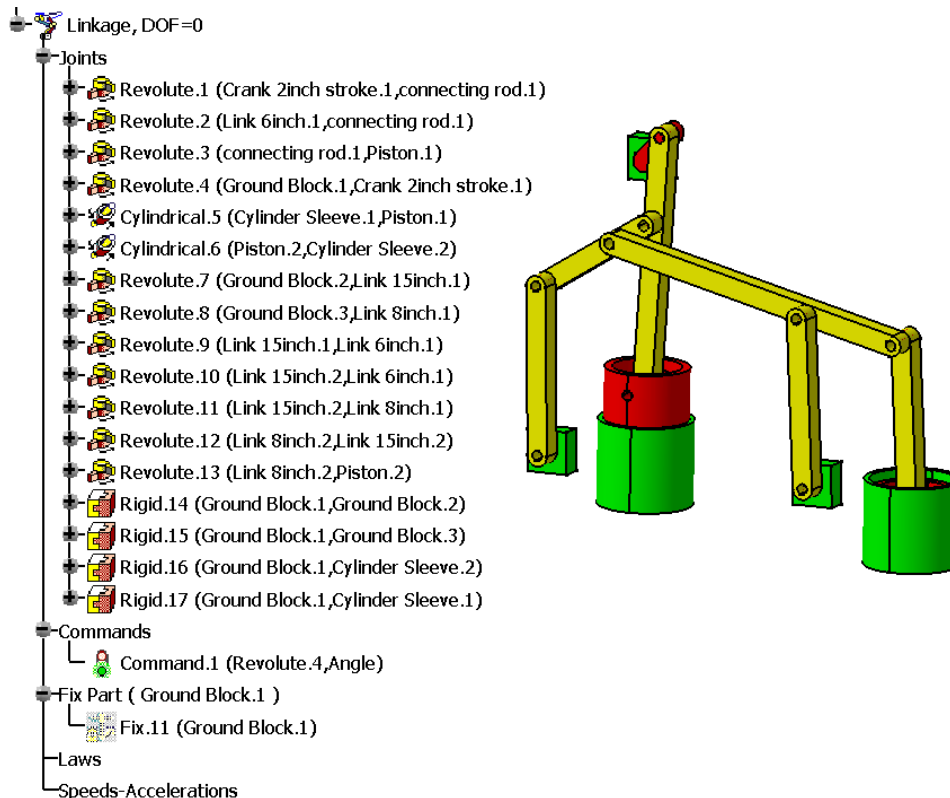
Save and close your document.

The previous exercise had you create the kinematic joints from assembly constraints using the *Auto Create* option. This works great for many cases, but you are leaving a lot of decisions up to CATIA. You may want to control which joints get created. By using the additional options in the assembly constraints conversion option, you can pick and choose which joints are created.

Advanced

Open the Assembly Constraints Advanced document in the *Assembly Constraints Advanced* **directory.** You should see a slider assembly. All of the objects have been constrained and the assembly can move with respect to constraints within Assembly Design.
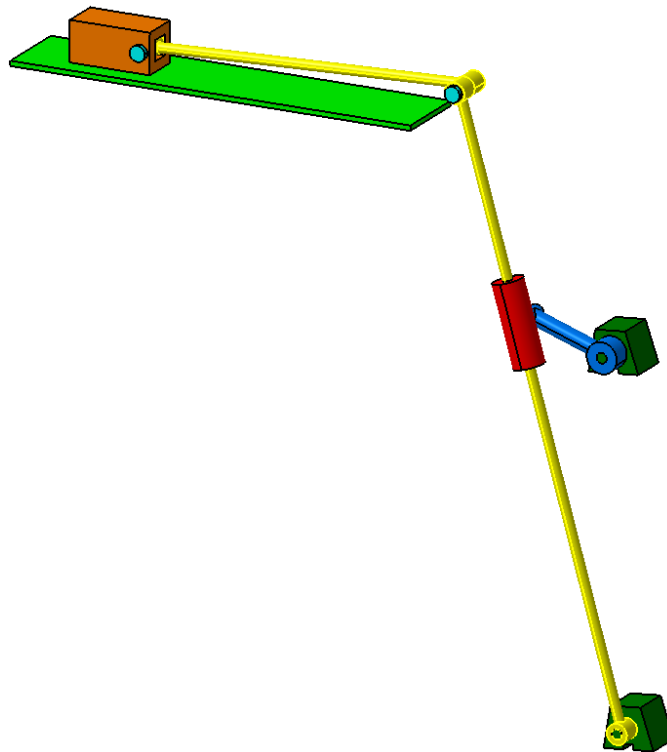
Select the Assembly Constraints Conversion icon. The *Assembly Constraints Conversion* window appears.

Select the *More* >> button. The window expands.
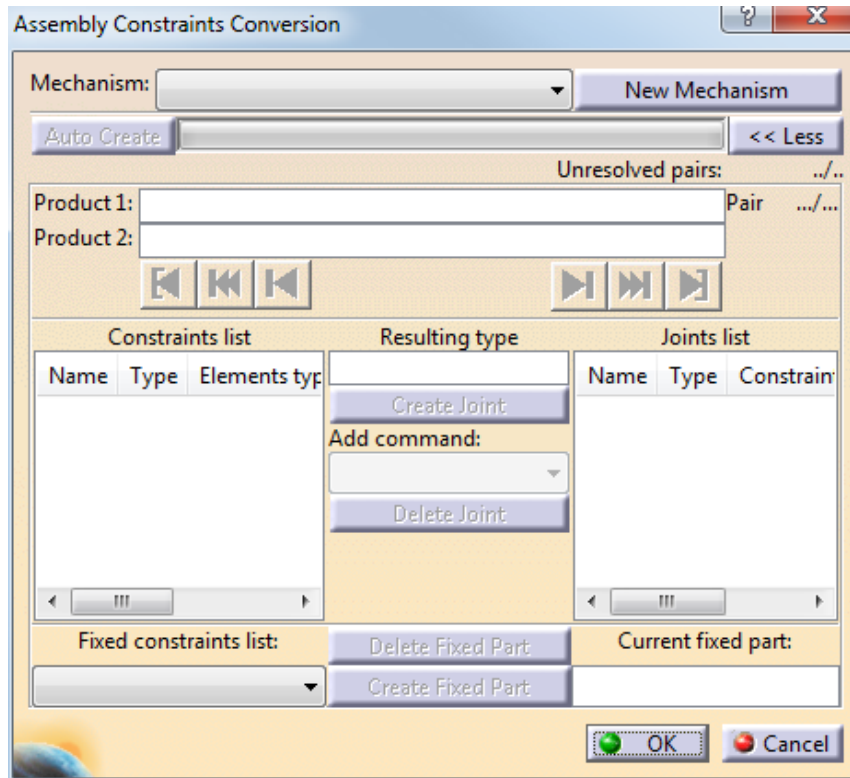
Product 1,2	Shows the two products involved
Constraints List	Shows the constraints that are associated to the pair of products shown
Resulting type	Shows the resulting joint that will be created based on the constraints that are selected in the *Constraints List*
Create Joint	Creates the joint shown in the *Resulting type*
Add Command	Adds a command to the joint
Delete Joint	Deletes the joint selected in the *Joints List*
Joints List	Shows the joints that are associated to the pair of products shown
Fix Constraints List	Shows all of the objects that have a fixed constraint
Delete Fix	Removes the fixed part shown in the *Current Fixed Part* box
Create Fix	Makes the object shown in the *Fix Constraints List* the fixed part for the mechanism
Current Fixed Part	Shows the fixed part for the mechanism

Select the *New Mechanism* button and create a mechanism called Slider. Items appear in the boxes. The first pair is shown. In the *Fix Constraints List* you should see the first fix constraint which is on the *Ground Block.2* component.

Select the *Create Fixed Part* button. The *Ground Block.2* component becomes the *Current Fixed Part*. A *Question* window appears stating that there are more than one fix constraints in your assembly. You have the option of creating rigid joints between those parts..
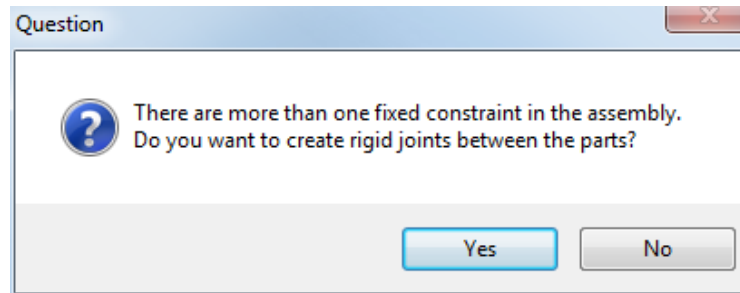
Select *Yes*. Two rigid joints were created and added to your mechanism. You should notice that the two components that are in the first pair are highlighted in the graphic area.

Select the *Coincidence* constraint in the *Constraints List*. The *Resulting type* is *Cylindrical* when only that constraint is considered.

Select the *Surface Contact* constraint in the *Constraints List*. The *Resulting type* is *Planar* when only that constraint is considered.

Select both constraints in the *Constraints List*. You may need to use the Ctrl key to select both at the same time. The *Resulting type* is *Revolute*. This is the joint that you want and you want it to drive the mechanism.

Select the drop down for the *Add Command*. The available commands for this joint appears.

Select the *Angle* command. You are now ready to create the joint.

Select the *Create Joint* button. The joint is created and there are no more constraints available for this pair of components. You have 0 degrees of freedom in your mechanism.

Select the Step Forward icon. ▶❙ This moves to the next pair of components. The two components highlight. You will want a revolute joint between these two as well.

Select both of the constraints, the *Resulting type* should show *Revolute* and select the *Create Joint* button. You have 1 degree of freedom since you did not assign a command to the joint. This will be taken care of by creating additional joints.

Select the Step Forward icon. ▶❙ This moves to the next pair of components. The two components highlight. This is an offset constraint between the two ground blocks. There is no need to create a joint for this since they already have a rigid joint between them.

Select the Step Forward icon. ▶❙ This moves to the next pair of components without creating a joint. The two components highlight. You will want a revolute joint between these two components.

Select both of the constraints, the *Resulting type* should show *Revolute* and select the *Create Joint* button. You now have 2 degrees of freedom. Your mechanism should appear similiar to the one shown below at this moment.

```
⊟ 🛠 Slider, DOF=2
   ⊟ Joints
      ⊞ 📙 Rigid.1 (Ground Block.2,Ground Block.1)
      ⊞ 📙 Rigid.2 (Ground Block.2,Piston Ground Plate.1)
      ⊞ 🦿 Revolute.3 (Crank-Slider Quick-Return.1,Ground Block.1)
      ⊞ 🦿 Revolute.4 (Link Connector.1,Crank-Slider Quick-Return.1)
      ⊞ 🦿 Revolute.5 (Link 15inch.1,Ground Block.2)
   ⊟ Commands
      └ 🚦 Command.1 (Revolute.3,Angle)
   ⊟ Fix Part ( Ground Block.2 )
      └ 🔲 Fix.1 (Ground Block.2)
```
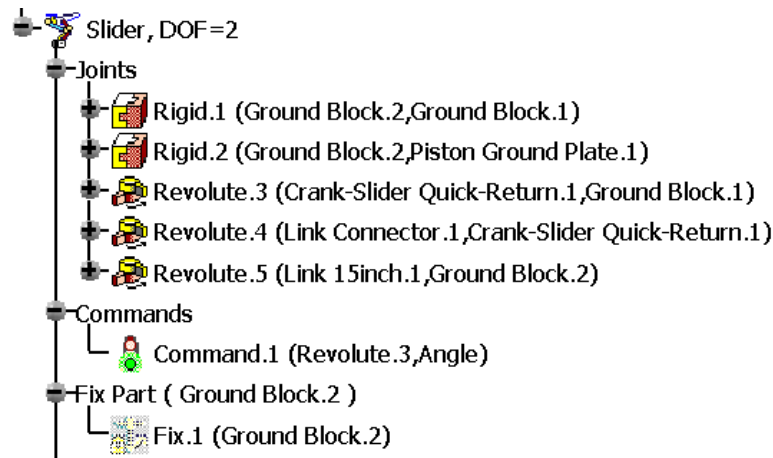
Select the Step Forward icon. ▶❙ This moves to the next pair of components and shows that they already have a rigid joint defined between them.

Select the Step Forward icon. ▶❙ This moves to the next pair of components without creating a new joint. The two components highlight. You will want a revolute joint between these two components.

Select both of the constraints, the *Resulting type* should show *Revolute* and select the *Create Joint* button. You now have 3 degrees of freedom.

Select the Step Forward icon. ▶❙ This moves to the next pair of components. The two components highlight. This time you are going to create a cylindrical joint.

Select the *Coincidence* constraint, the *Resulting type* should show *Cylindrical* and select the *Create Joint* button. The degrees of freedom reduces to 1.

Select the Step Forward icon. ▶❙ This moves to the next pair of components. These constraints are between the pin and the link. You do not need a joint between them since the pin should be rigid to the link.

Select the Step Forward icon. ▶❙ This moves to the next pair of components. You will want a revolute joint between these two components.

Select both of the constraints, the *Resulting type* should show *Revolute* and select the *Create Joint* button. You now have 2 degrees of freedom again.

Select the Step Forward icon. ⏭ This moves to the next pair of components. These constraints are between the pin and the sliding block. Once again, you do not need a link between them since the pin should be rigid to the block.

Select the Step Forward icon. ⏭ This moves to the next pair of components. You will want a planar joint between these two components.

Select the constraint, the *Resulting type* should show *Planar* and select the *Create Joint* button. You now have 0 degrees of freedom. You are also at the end of the conversion.

Select *OK*. Your mechanism should appear similar to the one shown below.
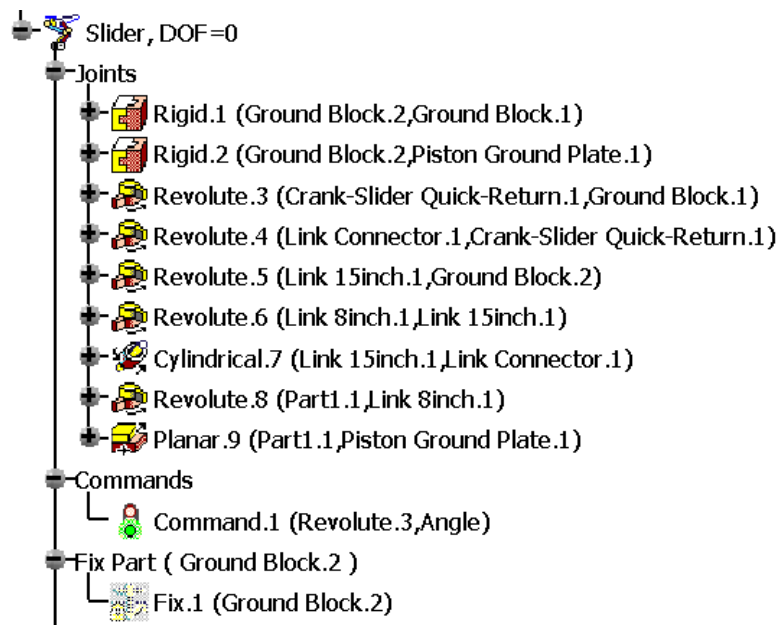
```
⊡ 🖑 Slider, DOF=0
  ⊟ Joints
      ⊞ 📇 Rigid.1 (Ground Block.2,Ground Block.1)
      ⊞ 📇 Rigid.2 (Ground Block.2,Piston Ground Plate.1)
      ⊞ 🖑 Revolute.3 (Crank-Slider Quick-Return.1,Ground Block.1)
      ⊞ 🖑 Revolute.4 (Link Connector.1,Crank-Slider Quick-Return.1)
      ⊞ 🖑 Revolute.5 (Link 15inch.1,Ground Block.2)
      ⊞ 🖑 Revolute.6 (Link 8inch.1,Link 15inch.1)
      ⊞ 🖑 Cylindrical.7 (Link 15inch.1,Link Connector.1)
      ⊞ 🖑 Revolute.8 (Part1.1,Link 8inch.1)
      ⊞ 🖑 Planar.9 (Part1.1,Piston Ground Plate.1)
  ⊟ Commands
      └ 🔒 Command.1 (Revolute.3,Angle)
  ⊟ Fix Part ( Ground Block.2 )
      └ 🔩 Fix.1 (Ground Block.2)
```

Select the Simulation with Commands icon, select *On request*, drag the slider all the way to the right, change the *Number of steps* to 40 and select the Play Forward icon. 🔵 ▶ The mechanism goes in motion. Notice that the two pins did not move. You never defined the rigid constraints with the pins.

Select the *Reset* button and select *Close*. The window closes.

Create a rigid joint between the pin and the block and one between the other pin and the long link.

Simulate the mechanism again. This time the pins move with mechanism.

Close your simulation. Your final mechanism should appear similar to the one shown below.

```
♦-Mechanisms
    ♦-🎿 Slider, DOF=0
        ♦-Joints
            ♦-🔳 Rigid.1 (Ground Block.2,Ground Block.1)
            ♦-🔳 Rigid.2 (Ground Block.2,Piston Ground Plate.1)
            ♦-🔩 Revolute.3 (Crank-Slider Quick-Return.1,Ground Block.1)
            ♦-🔩 Revolute.4 (Link Connector.1,Crank-Slider Quick-Return.1)
            ♦-🔩 Revolute.5 (Link 15inch.1,Ground Block.2)
            ♦-🔩 Revolute.6 (Link 8inch.1,Link 15inch.1)
            ♦-🔧 Cylindrical.7 (Link 15inch.1,Link Connector.1)
            ♦-🔩 Revolute.8 (Part1.1,Link 8inch.1)
            ♦-🔧 Planar.9 (Part1.1,Piston Ground Plate.1)
            ♦-🔳 Rigid.10 (Pin 2inch.2,Part1.1)
            ♦-🔳 Rigid.11 (Pin 2inch.1,Link 15inch.1)
        ♦-Commands
            └─🔒 Command.1 (Revolute.3,Angle)
    ♦-Fix Part ( Ground Block.2 )
        └─🔲 Fix.1 (Ground Block.2)
    ├─Laws
    └─Speeds-Accelerations
```

Save and close your document. You are going to see what happens if you used the *Auto Create* option instead of manually converting the constraints to joints.

Open the original Assembly Constraints Advanced document again.
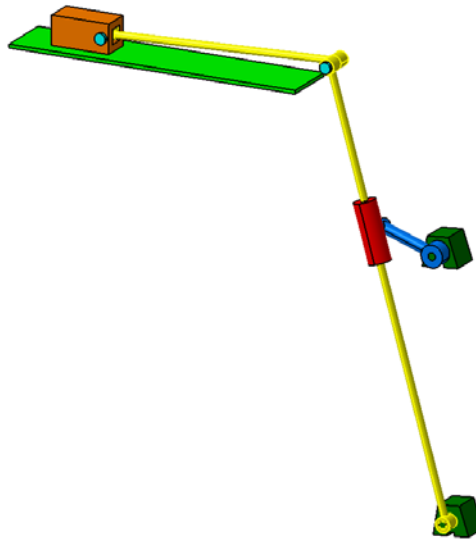
Select the Assembly Constraints Conversion icon. The *Assembly Constraints Conversion* window appears.

Select the *New Mechanism* button and create a mechanism called <u>Slider</u>. The *Auto Create* button becomes available.

Select the *Auto Create* button. Joints are automatically defined based on the assembly constraints and the window now shows there are 0 unresolved pairs.
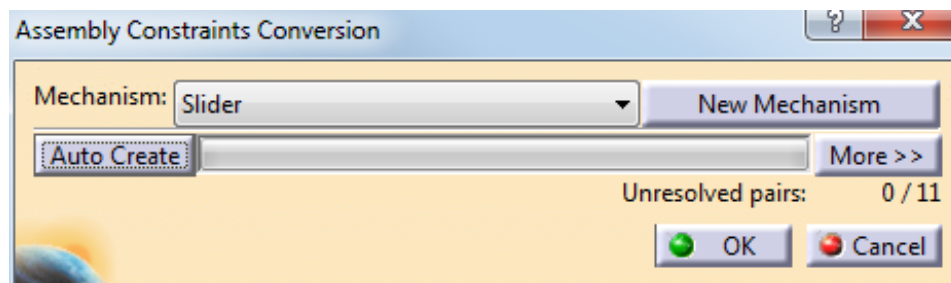
Select *OK*. Notice that you still have 3 degrees of freedom. You need to add a command to one of the joints.

Double select on *Revolute.1* from the specification tree. The *Joint Edition* window appears.

Select the *Angle driven* option and select *OK*. You still have 2 degrees of freedom. This is because it generated constraints with the pins.

Delete the *Revolute.7* and *Revolute.9* joints. You now have 0 degrees of freedom.

Delete the *Planar.3* joint as well since it is unnecessary. The degrees of freedom do not change since this joint had no effect on the mechanism. The reason this joint is unnecessary is there is already a rigid joint defined between them.

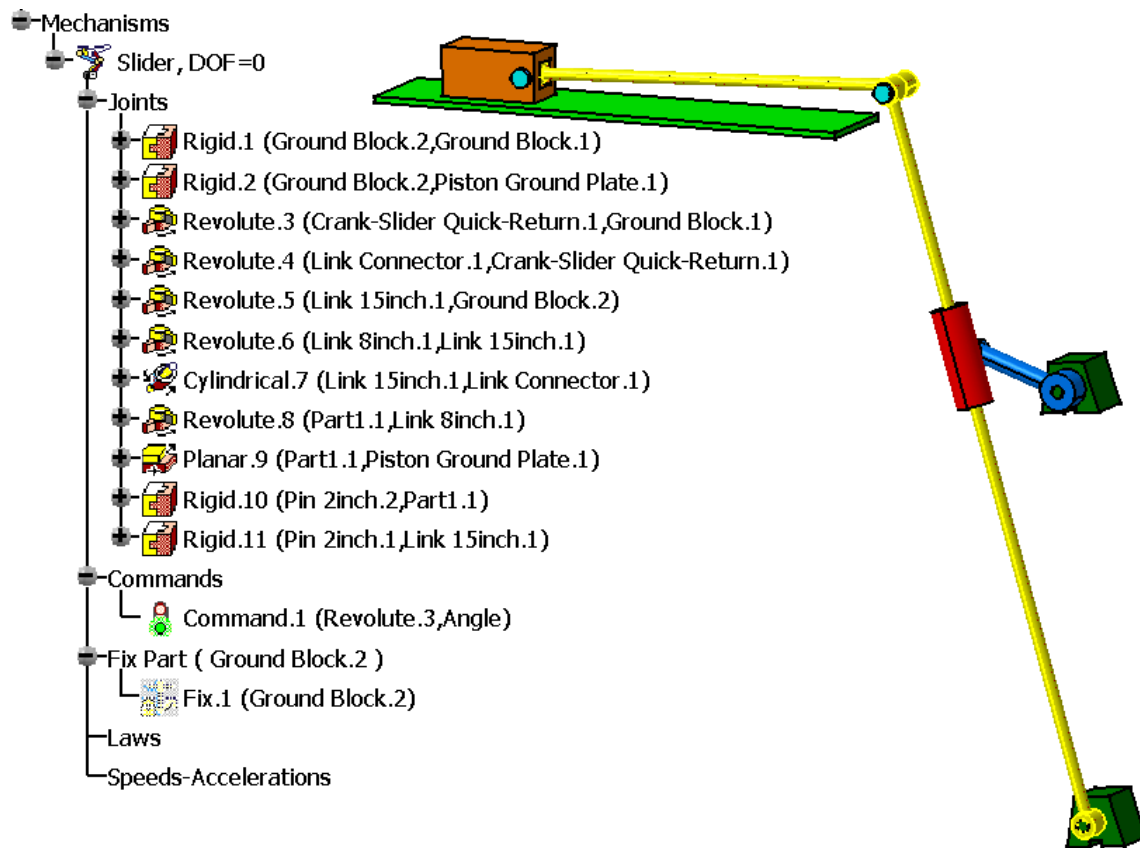**Select the Simulation with Commands icon, select *On request*, drag the slider all the way to the right, change the *Number of steps* to 40 and select the Play Forward icon.** The mechanism goes in motion. Notice that the two pins did not move. You still need to define rigid joints between the pins and respective parts.

Select *Close*. The window closes. You can see that when you use *Auto Create* it may make mistakes on the joints that it creates. This requires that you check the mechanism out before calling it good. It is up to you to determine which method works best for the assembly that you are working on.

Close your document. There is no reason to save.

Law Review - Rules

In this review, you will be applying the different types of laws to a landing gear assembly. This will show how laws can simulate multiple commands simultaneously, some with more control and ease than others.

Open the Law Review document from the *Law Review* directory. The Landing Gear assembly should appear. All of the joints, limits, and commands have already been created for you.
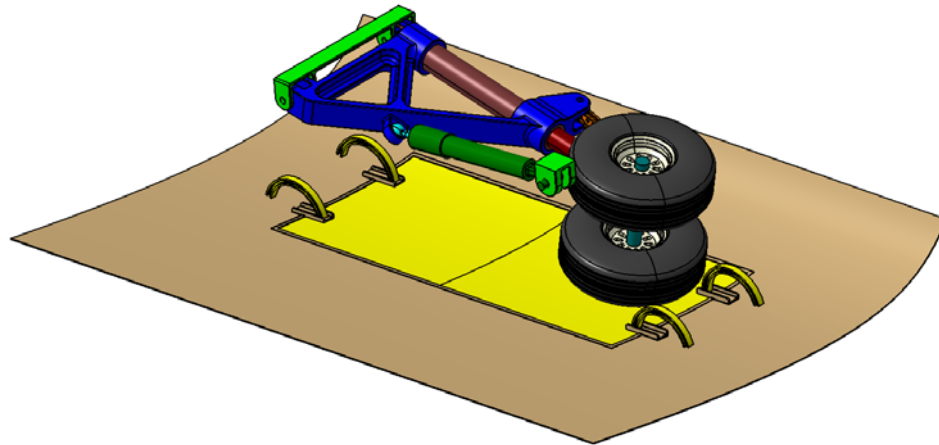
Expand the *Mechanisms* branch. Notice that there are several commands to control this mechanism. You will be first creating a Knowledgeware Rule to control these commands.

Create a new Rule with a name and description of your choosing. Remember, you must switch to the Knowledge Advisor workbench.

Select *OK*. The *Rule Editor : Knowledgeware Rule Active* window will appear. You will be writing a rule that makes both the doors lower at the same rate, after they are partially open the landing gear will begin to lower as well. The two doors will be fully open before the landing gear is completely down.

Create the first If-Then statement for KINTime to be less than or equal to 6 seconds.
This will be very similar to the process you used earlier. Make sure you select the mechanism from the tree first, then double select the appropriate member from the *Members of All* section within the *Rule Editor* window in order to add it to the If-Then statement.

The *Then* statement is going to be a little different. Anytime you are controlling multiple commands you will need to enclose them all in braces { }.

Set the *Left Door Angle* command equal to 5 degrees per second.

Set the *Right Door Angle* command equal to the Left Door Angle command.

Set the *Lifting Cylinder Length* equal to 0 inches. This will keep the landing gear stationary for the first six seconds. Be sure to end this statement with a brace.

Your rule should now look like the following.

```
/*Rule created by nathan 3/29/2012*/
if `Landing Gear\KINTime` <=6s
{
        `Landing Gear\Commands\Left Door Angle\Angle` = (`Landing Gear\KINTime` /1s)*5deg
        `Landing Gear\Commands\Right Door Angle\Angle` = `Landing Gear\Commands\Left Door Angle\Angle`
        `Landing Gear\Commands\Lifting Cylinder Length\Length` = 0in
}
```

Start another If-Then statement for the time greater then 6 seconds and less then or equal to 26 seconds.

Set the *Left Door Angle* command equal to 5 degrees per second. Be sure to subtract the initial time from the KINTime and then add the ending position of the previous step to the equation.

Set the *Right Door Angle* command equal to the Left Door Angle command.

Set the *Lifting Cylinder Length* equal to 0.5 inches per second. Your rule should now look like the following.

```
/*Rule created by nathan 3/29/2012*/
if `Landing Gear\KINTime` <=6s
{
        `Landing Gear\Commands\Left Door Angle\Angle` = (`Landing Gear\KINTime` /1s)*5deg
        `Landing Gear\Commands\Right Door Angle\Angle` = `Landing Gear\Commands\Left Door Angle\Angle`
        `Landing Gear\Commands\Lifting Cylinder Length\Length` = 0in
}
if `Landing Gear\KINTime` >6s and `Landing Gear\KINTime` <=26s
{
        `Landing Gear\Commands\Left Door Angle\Angle` = (`Landing Gear\KINTime`-6s) /1s*5deg+30deg
        `Landing Gear\Commands\Right Door Angle\Angle` = `Landing Gear\Commands\Left Door Angle\Angle`
        `Landing Gear\Commands\Lifting Cylinder Length\Length` = (`Landing Gear\KINTime` -6s)/1s*0.5in
}
```

Now you want the doors to stop moving and the landing gear to continue lowering.

Start another If-Then statement for the time greater then 26 seconds and less then or equal to 38 seconds.

Set the *Left Door Angle* command equal to 130 degrees. This is the ending value after the doors have traveled 5 degrees per second for 26 seconds. This will keep the doors at a constant 130 degrees for the duration of this step.

Set the *Right Door Angle* command equal to the Left Door Angle command.

Set the *Lifting Cylinder Length* equal to 0.5 inches per second. Be sure to subtract the initial time from the KINTime and then add the ending position of the previous step to the equation.

Your rule should now look like the following.

```
/*Rule created by nathan 3/29/2012*/
if `Landing Gear\KINTime` <=6s
{
        `Landing Gear\Commands\Left Door Angle\Angle` = (`Landing Gear\KINTime` /1s)*5deg
        `Landing Gear\Commands\Right Door Angle\Angle` = `Landing Gear\Commands\Left Door Angle\Angle`
        `Landing Gear\Commands\Lifting Cylinder Length\Length` = 0in
}
if `Landing Gear\KINTime` >6s and `Landing Gear\KINTime` <=26s
{
        `Landing Gear\Commands\Left Door Angle\Angle` = (`Landing Gear\KINTime`-6s) /1s*5deg+30deg
        `Landing Gear\Commands\Right Door Angle\Angle` = `Landing Gear\Commands\Left Door Angle\Angle`
        `Landing Gear\Commands\Lifting Cylinder Length\Length` = (`Landing Gear\KINTime` -6s)/1s*0.5in
}
if `Landing Gear\KINTime` >26s and `Landing Gear\KINTime` <=38s
{
        `Landing Gear\Commands\Left Door Angle\Angle` = 130deg
        `Landing Gear\Commands\Right Door Angle\Angle` = `Landing Gear\Commands\Left Door Angle\Angle`
        `Landing Gear\Commands\Lifting Cylinder Length\Length` = (`Landing Gear\KINTime` -26s)/1s*0.5in+10in
}
```

Your rule should now be ready to simulate your mechanism.

Select *OK* to the *Rule Editor* window.

Switch back to the Kinematics workbench.

Select the Simulate with Laws icon. The simulation window appears. An information window may appear stating the *Update all external references* option will be temporarily deactivated for the simulation. Select *OK* if necessary.

Change the *Maximum Time Bound* to be 38s, the length of your rule.

Change the *Number of steps* to 200.
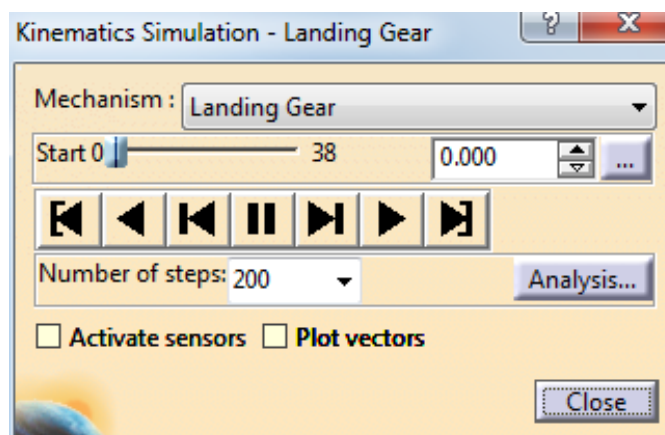
Select the Play forward icon. ▶ The doors should begin to open then the landing gear should lower.
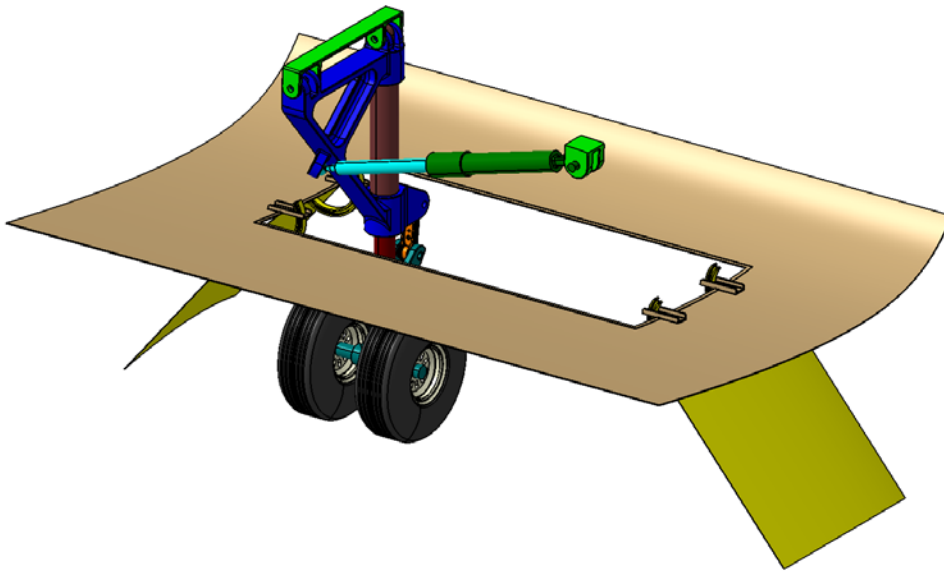
Select the Start icon. ◄|

Close the simulation window. This is how you go about creating a rule for a mechanism that has multiple commands and sequencing of events.

Save your document but do not close.