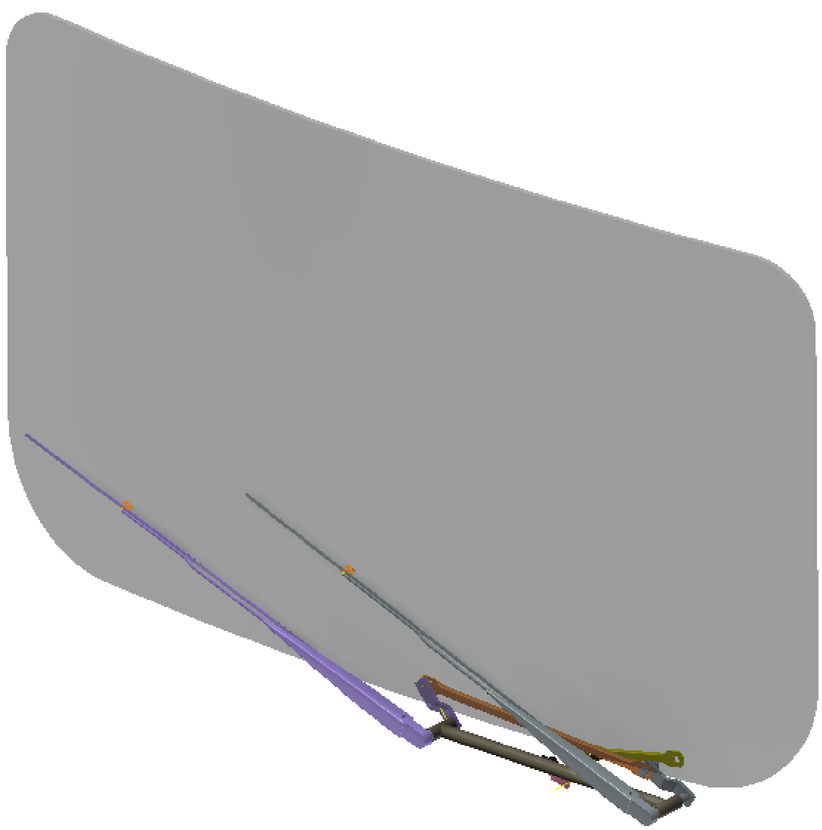
aWindshield Wiper Assembly

Within this project there are three separate projects that all work on completing dynamic simulation activities on a windshield wiper assembly. The project will cover creating and editing joints plus assigning loads. The Output Grapher will also be used in each project to analysis and view key critical data on the performance of the design.

1.1 Project 3A – Joint Properties and Defining Loads

In this project you create joints in a wiper assembly to drive the wiper arms. You impose motion on the drive arm and add resistive force to the wiper blades to simulate the friction of the blade on the windshield. Finally you use the Input Grapher to define the resistive force so that it is always opposed to the wiper motion.



ME 24-688 – Week 11

Windshield Wiper Assembly

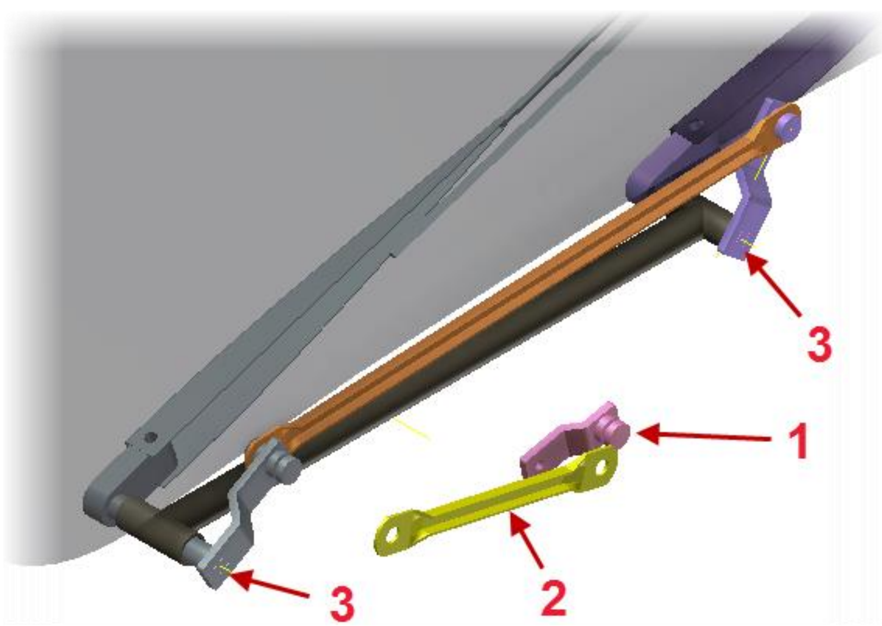
1. In this section of the project, you define the joints that connect the drive arm to the cranks that move the wiper subassemblies. Open the *WiperAssemblyDEC.iam* Autodesk Inventor assembly file.

2. Click **Environments tab** | **Begin panel** | **Dynamic Simulation**.

3. If required, click **No** to close the message window for viewing the standard tutorial.

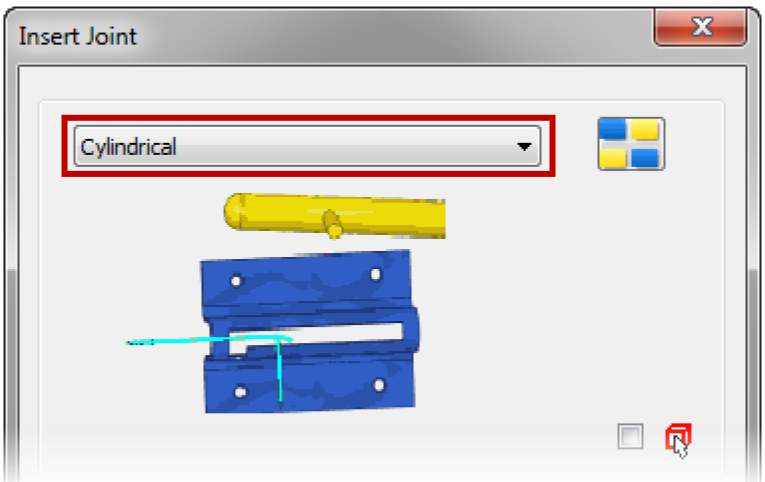
4. The model already has some setup items completed and joints created as a starting point for this project. On the **ViewCube**, click the top-right corner.

5. Review the assembly as shown below. The simulation requires a joint to control the rotation of the *Motor_Crank_Asm* (1). This subassembly is attached to the wiper motor and drives the *Crank_motor2* component (2), which drives the wiper subassemblies (3).

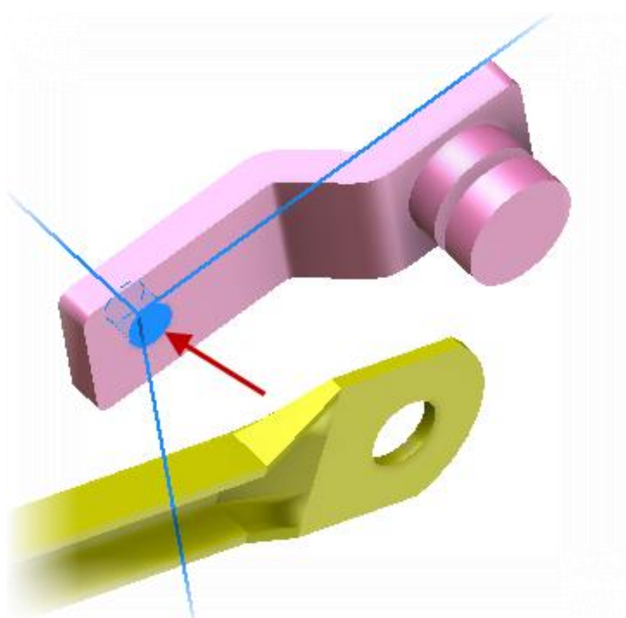


6. On the **Joint** panel, click **Insert Joint** to start the process for creating a new mechanical joint.

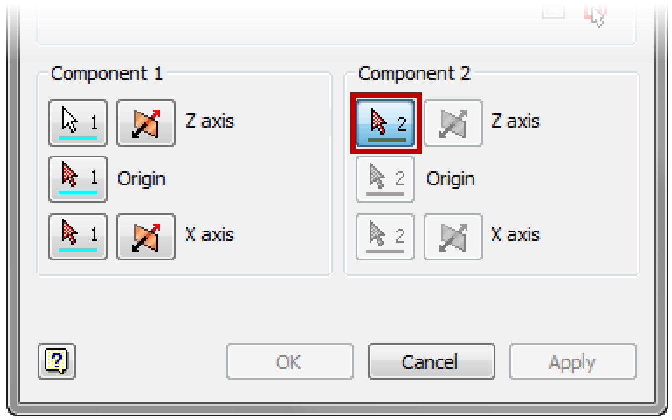
7. Select **Cylindrical** from the list. The Cylindrical joint has two (2) DOF one rotation and one translation.



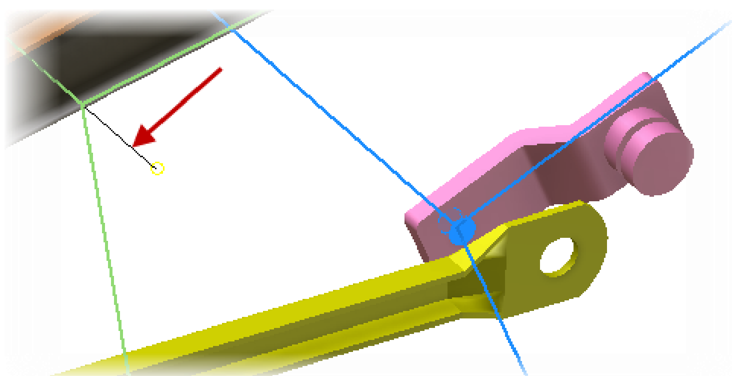
8. For the **Component 1 Z Axis** select the hole of the *Motor_Crank_Asm* as shown.



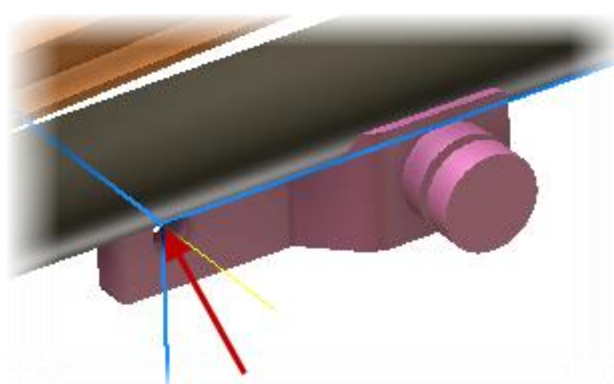
9. In the **Insert Joint** dialog box, under *Component 2*, click the second selection button.



10. Select the work axis, as shown.



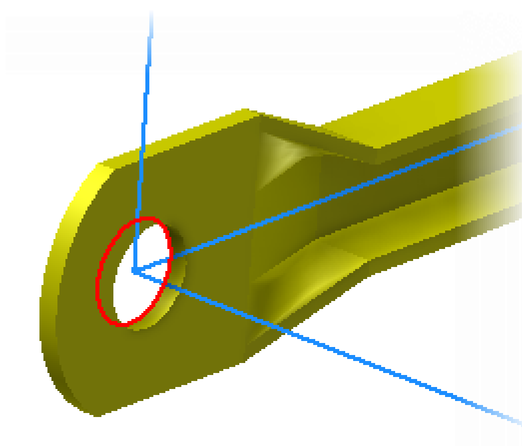
11. Click **OK**. The cylindrical joint enables *the Motor_Crank_Asm* to rotate freely around the work axis and move along the work axis.



12. On the **Joint** panel, click **Insert Joint** to start creating another joint.

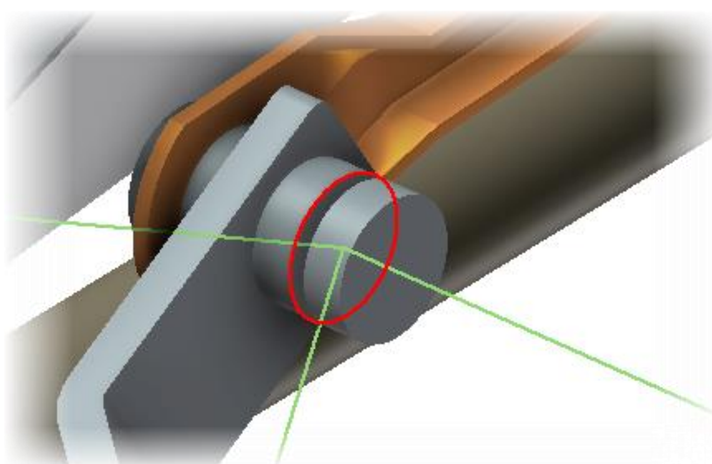
13. Select **Revolution** from the list of joint types. This revolution joint will have one rotation DOF around the Z Axis.

14. Select the circular edge as shown below for the **Component 1 Z Axis**.

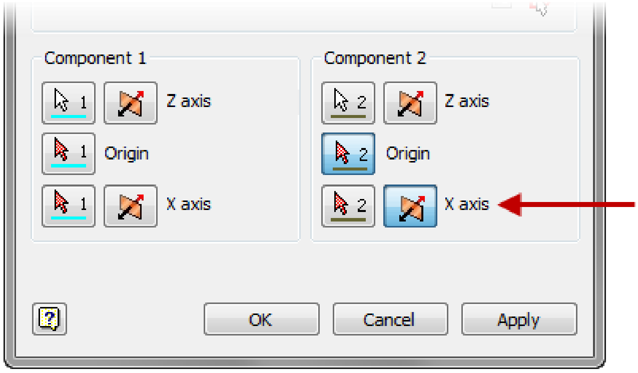


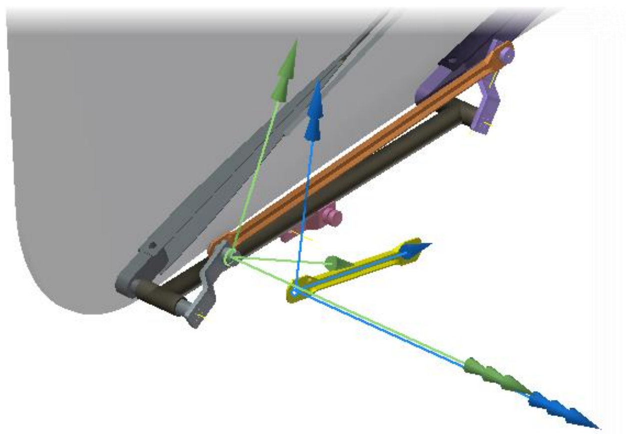
15. In the **Insert Joint** dialog box, under *Component 2*, click the second selection button.

16. Select the circular edge as shown.

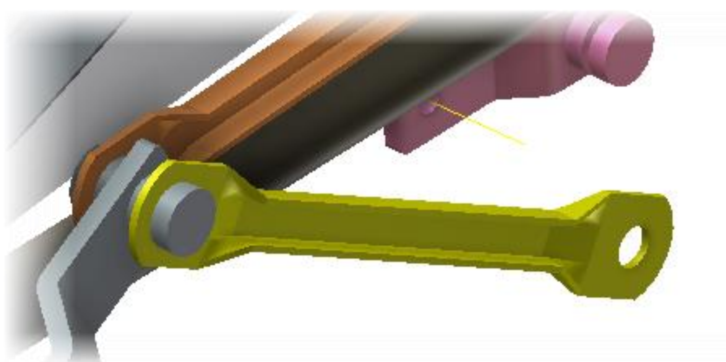


17. Under *Component 2*, click Flip X Axis Direction as shown, to reverse the direction of the X Axis. This will more closely align the two components in place.



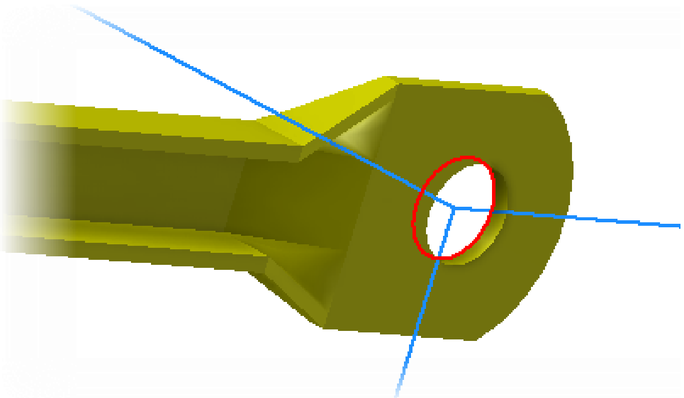


18. Click **Apply**. The *Crank_motor2* moves to the correct position. The **Insert Joint** dialog box remains open.



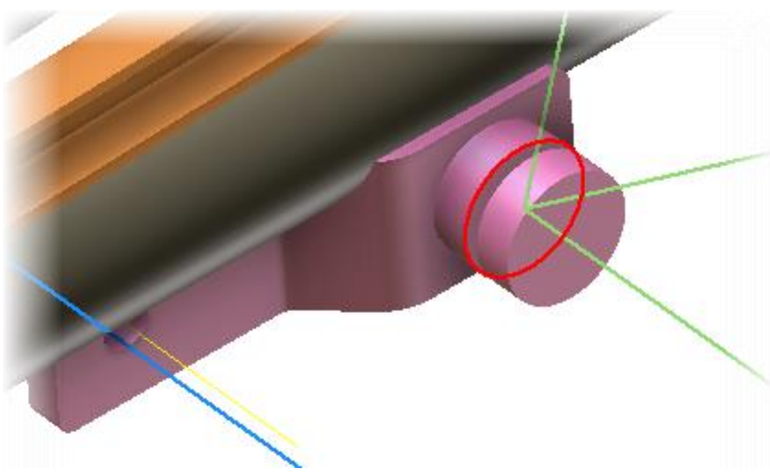
19. In the **Insert Joint** dialog box, select **Spherical** from the list. This joint will have three (3) DOF all rotational about a point. This type of joint is used to not over constrain the component.

20. Select the circular edge as shown.

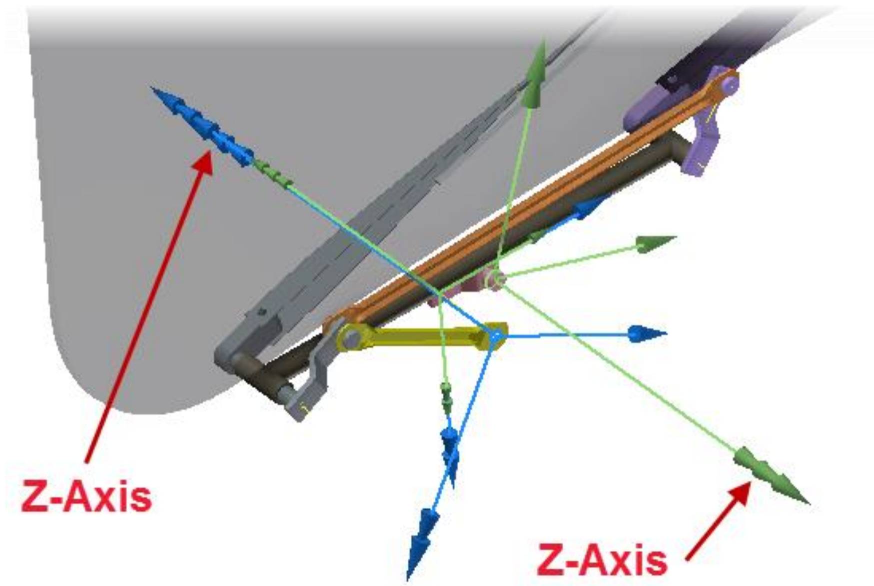


21. In the **Insert Joint** dialog box, under *Component 2*, click the second selection button.

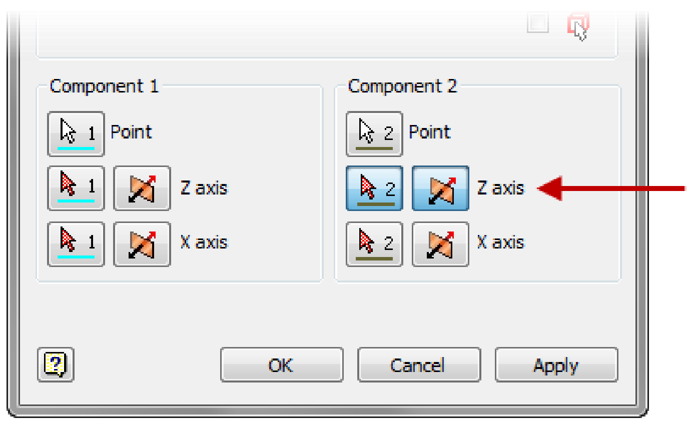
22. Select the circular edge as shown.



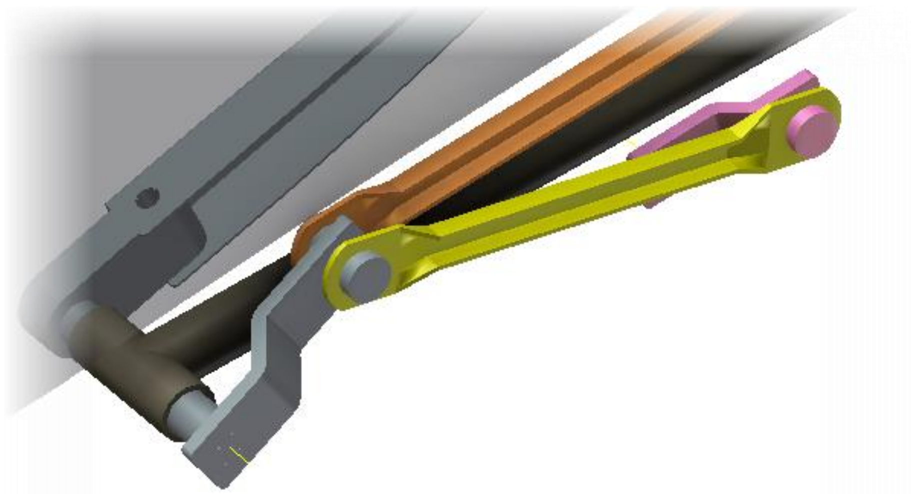
23. Review the alignment of the coordinate axes. The Z axis (1) of component 1 is pointing in the opposite direction of the Z axis (2) of component 2.



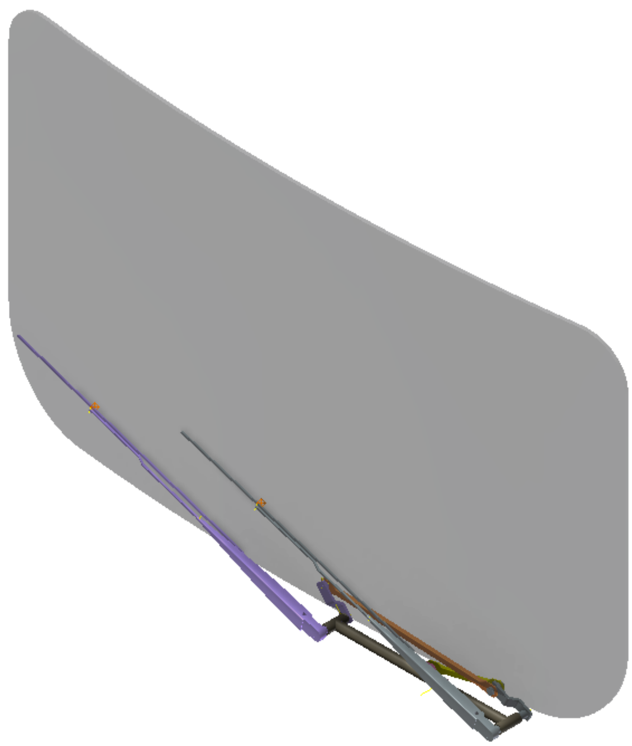
24: Under *Component 2*, click Flip Z Axis Direction as shown to reverse the direction of the Z axis.



24. Click **OK** to complete the joint and exit the **Insert Joint** dialog.



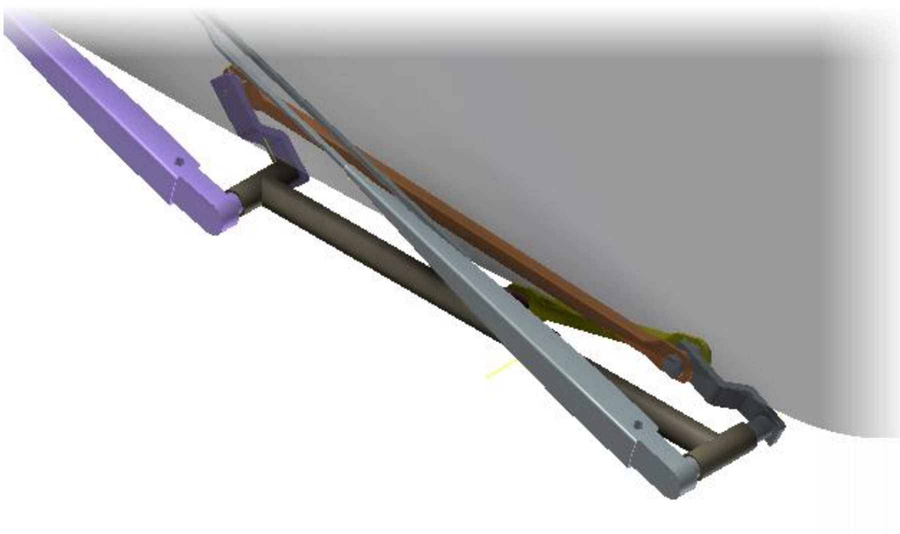
25. On the **ViewCube**, click **Home**.



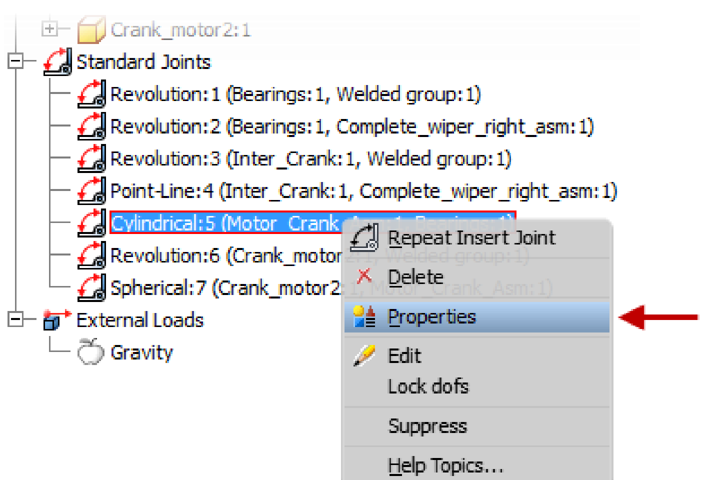
26. **Save** the assembly file.

27. In this section of the project, you impose motion on the *Motor_Crank_Asm* to simulate the wiper motor driving the wipers. Then you add a resistant force to the wipers to simulate the wiper blade rubbing against the windshield as it turns.

    - Zoom in on the assembly as shown.

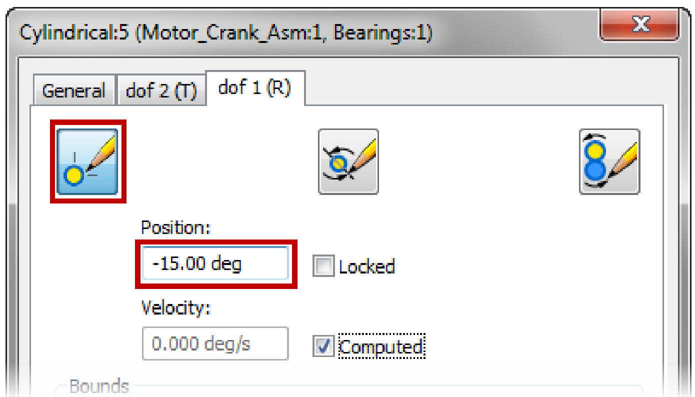


28. In the **Browser**, right-click *Cylindrical:5 (Motor_Crank_Asm:1, Bearings:1)*. Click **Properties**.



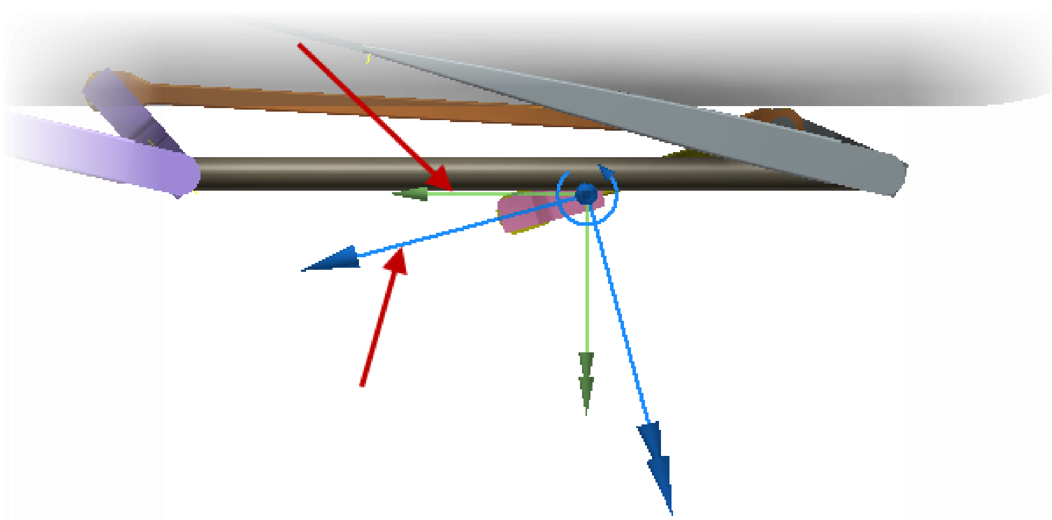
29. On the **dof 1 (R)** tab, do the following:

    - Confirm that **Edit Initial Conditions** is selected. This will specify the starting position of the components.
    - For **Position**, enter **-15 deg**
    - Click **OK**



30. On the **ViewCube**, click **Front**. Zoom in to the coordinate system axes.

31. Review the axes. The **-15 deg** angle is placed between the X axis of component 1 in the **cylindrical joint** and the X axis of component 2. This is now the initial starting position for the simulation.



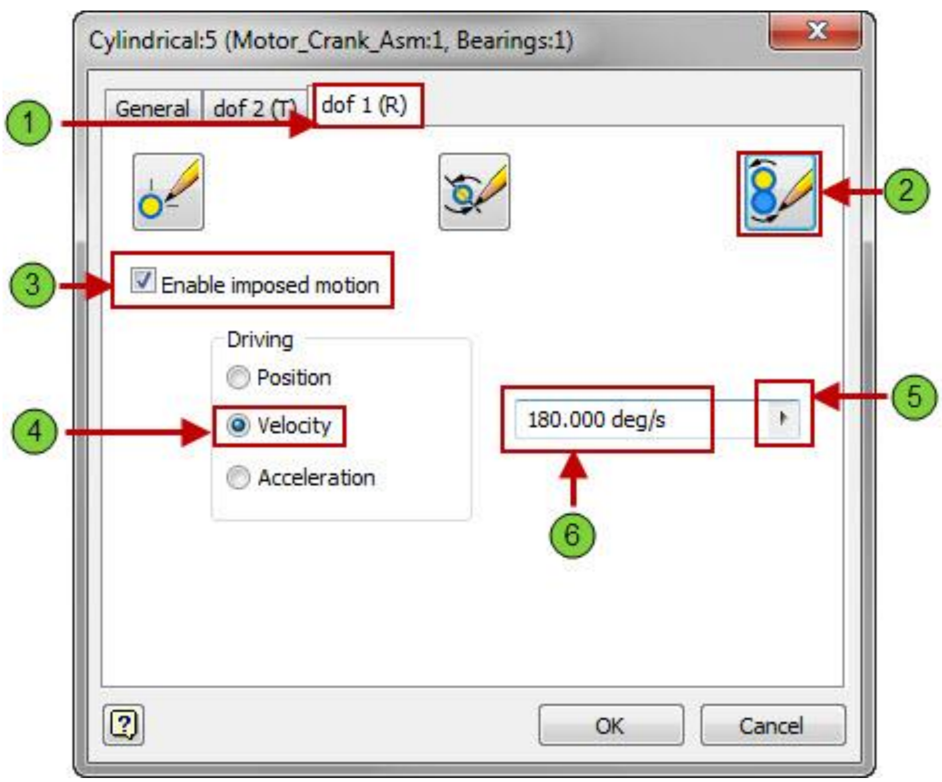
32. On the **ViewCube**, click **Home**.

33. In the **Browser**, right-*click Cylindrical:5 (Motor_Crank_Asm:1, Bearings:1).* Click **Properties**.

34. On the **dof 1 (R)** tab, do the following:

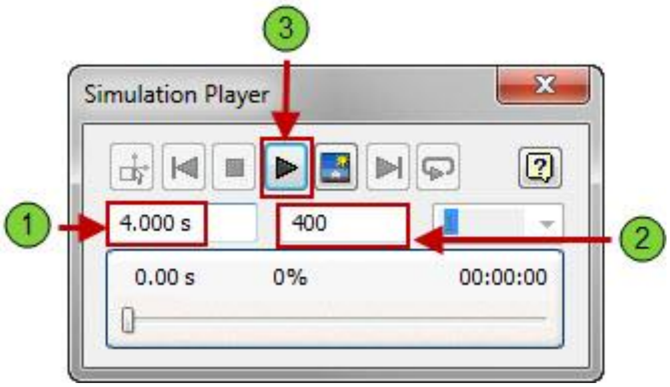
- Click **Edit Imposed Motion**
- Select the **Enable Imposed Motion** check box
- Under **Driving**, select **Velocity**
- Click the **Arrow**. Select **Constant Value**
- Enter **180 deg/s**
- Click **OK**

This will set the constraint to rotate about the Z axis 180 degree per each second of the simulation.



35. In the **Simulation Player**, do the following:

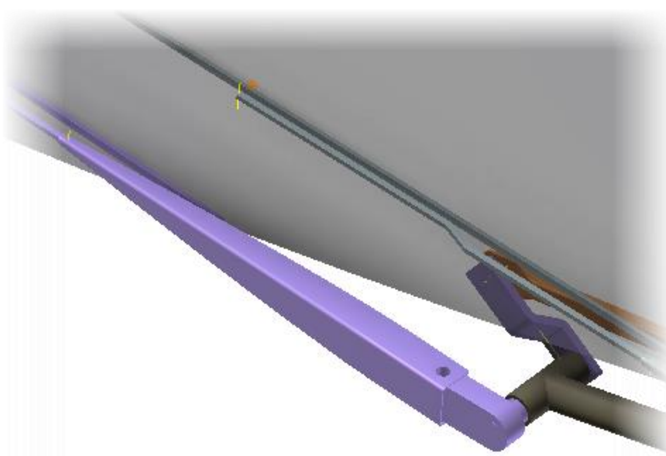
- In the **Final Time** window, enter **4 s**. This simulates two full revolutions.
- Press **TAB.** In Images, the value should change to **400** to capture 400 frames during the simulation.
- Click **Run** or **Replay the Simulation**.



With the simulation set to four seconds the *Motor_Crank_Asm* component will make two complete revolutions.

36. In the **Simulation Player**, click **Construction Mode**.

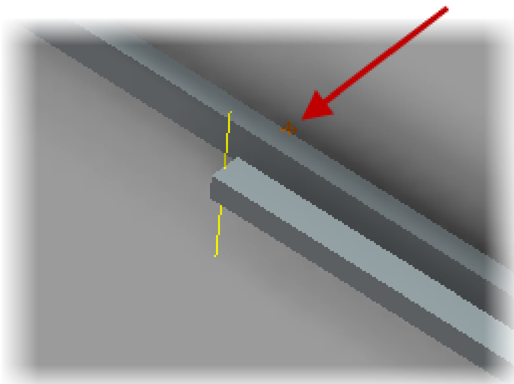
37. **Zoom** in on the assembly as shown.



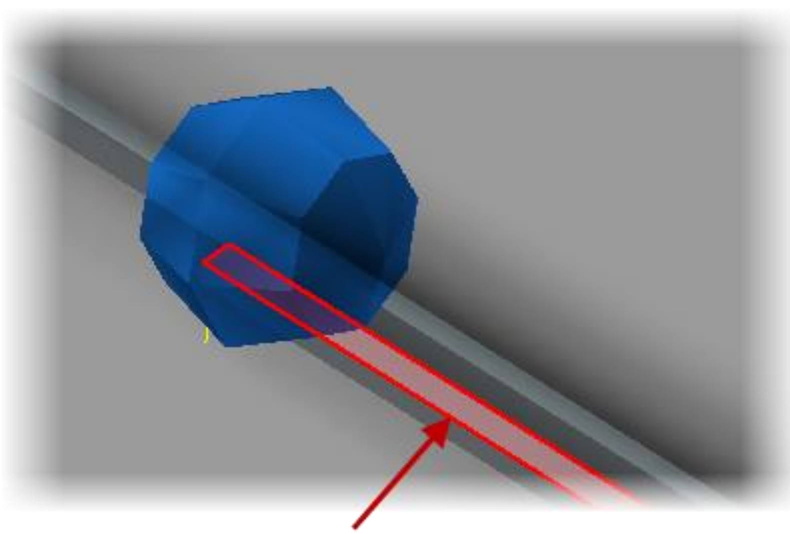
38. **Save** your Assembly file.

39. On the **Load** panel, click **Force**.

40. Select the work point on the wiper blade, as shown.

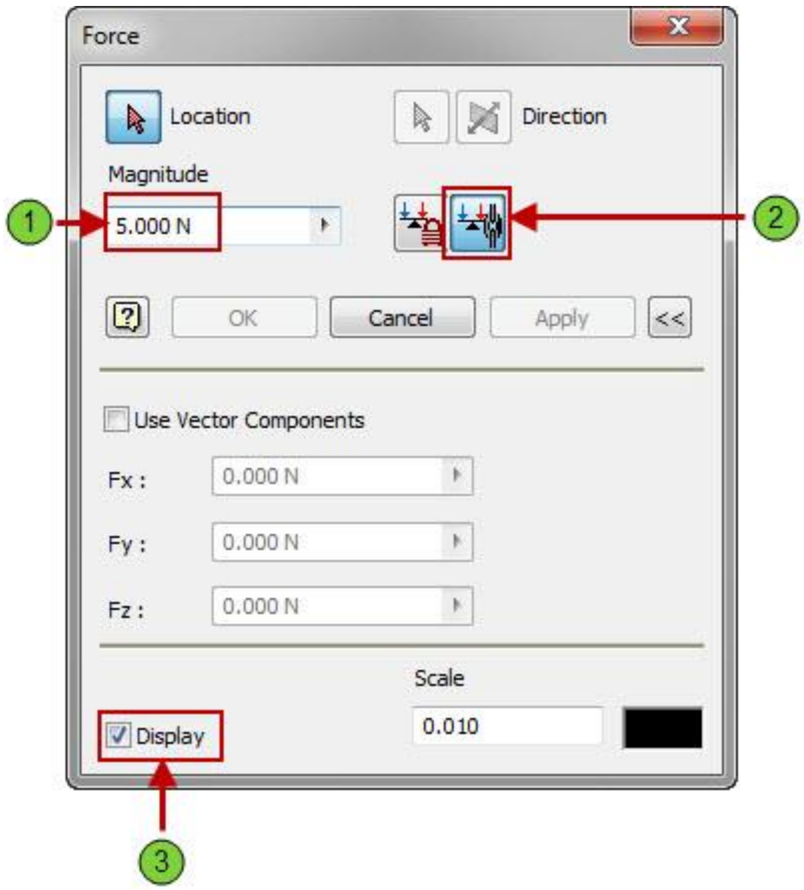


41. Select the flat face of the wiper arm, as shown.

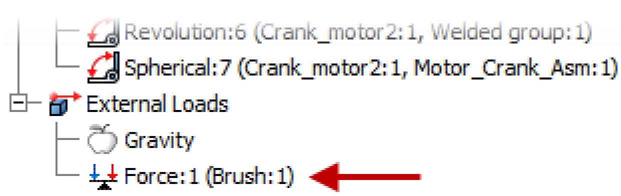


42. In the **Force** dialog box, do the following:

- For Magnitude, enter **5 N**.
- Click **Associative Load Direction**. This option causes the force to maintain its relationship to the location point.
- Click the **<< More** button
- Select the **Display** check box. This displays the force direction when you run a simulation.
- Click **OK**.

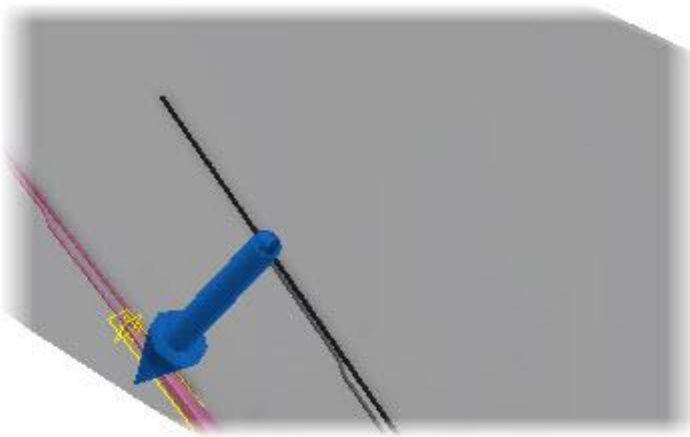


43. Review the browser. The **Force** is added beneath **the External Loads** node.



44. **Save** the assembly file.

45. In the **Simulation Player**, click **Run** or **Replay the Simulation.** The force arrow is displayed on the wiper blade during the simulation, as shown.

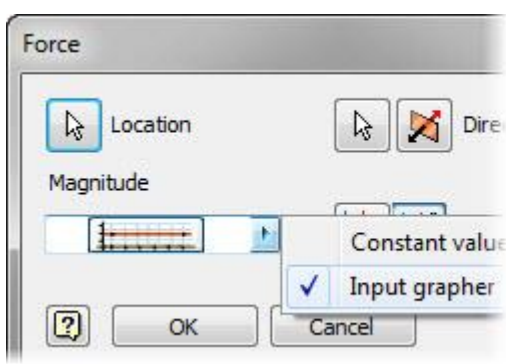


The resistive force maintains the same direction on the wiper throughout the simulation. The resistive force of the wiper should always be opposite to the motion. You use the **Input Grapher** to change the direction of the force when the wiper changes direction.

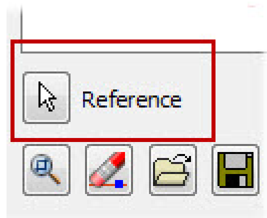
46. In the **Simulation Player**, click **Construction Mode**.

47. In the **Browser**, right-click *Force1 (Force on Brush:1).* Click **Edit**.

48. In the **Force** dialog box, click the **Arrow** in the **Magnitude** edit box. Click **Input Grapher**.

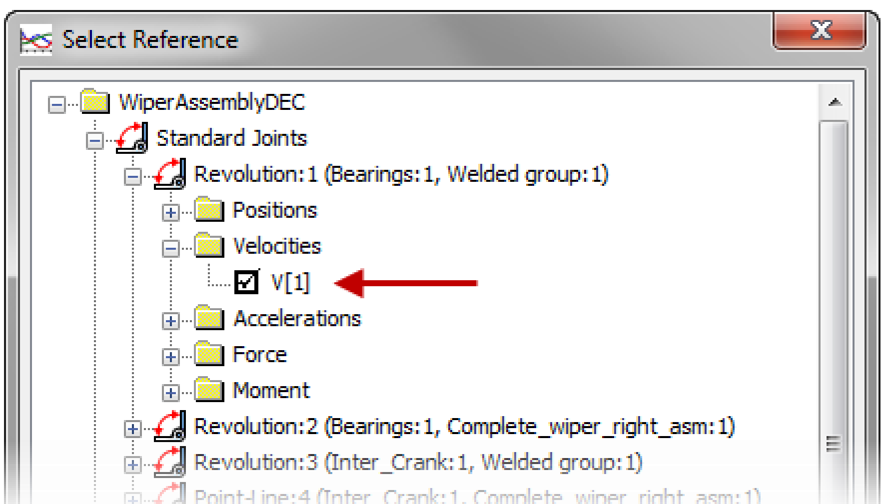


49. In the **Magnitude** dialog box, click Select **Reference**.



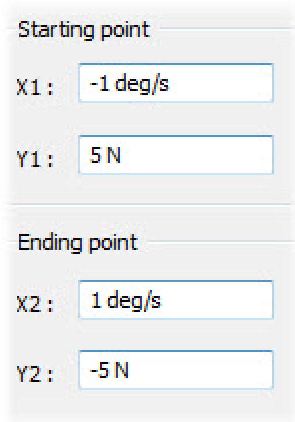
50. In the **Select Reference** dialog box, do the following:

- Expand **Standard Joints**
- Expand *Revolution:1 (Bearings:1, Welded group1)*
- Expand *Velocities*
- Select the *V[1]* check box
- Click **OK**



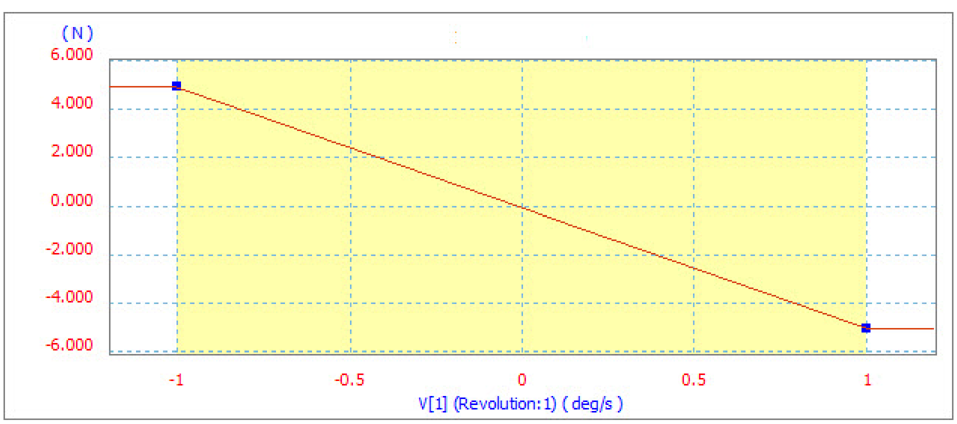
51. In the **Magnitude** dialog box, under **Starting Point**, do the following:

- For **X1**, enter **–1 deg/s**.
- For **Y1**, enter **5 N**.
- For **X2**, enter **1 deg/s**.
- For **Y2**, enter **-5 N**.



Between **-1 deg/s** velocity and **1 deg/s** velocity, the resistant force reverses itself, avoiding a discontinuity or immediate switch in the resistive force.

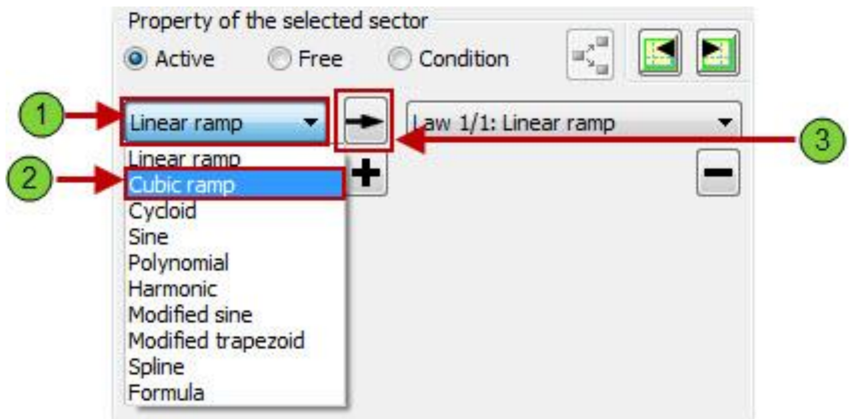
52. In the **Magnitude** dialog box, the graph is updated to reflect the values in the **Starting Point** and **Ending Point** areas. The ramp area is shaded in the graph.



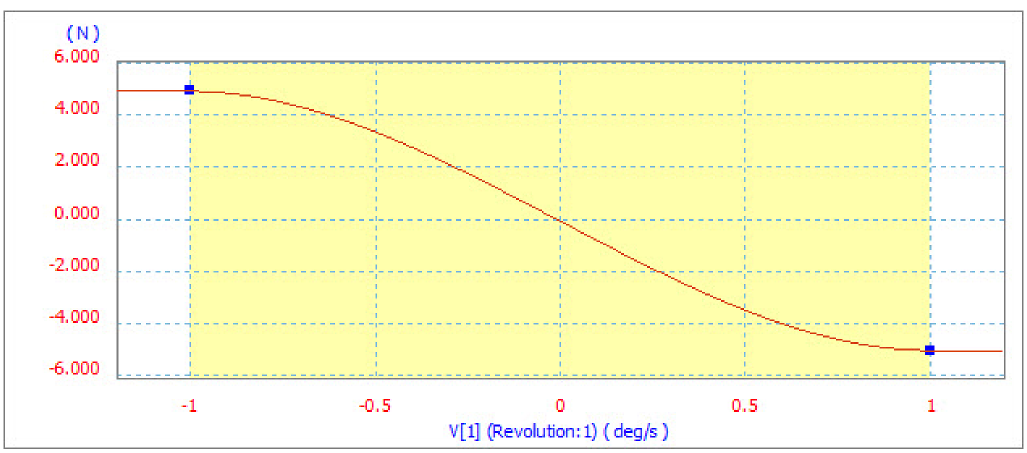
To create a smooth transition in the resistive force, you can change the ramp from a linear ramp to a cubic ramp.

53. In the **Magnitude** dialog box, under **Property of the Selected Sector**, do the following:

- Expand the list of available laws.
- Select **Cubic Ramp**.
- Click **Replace the Current Law**.

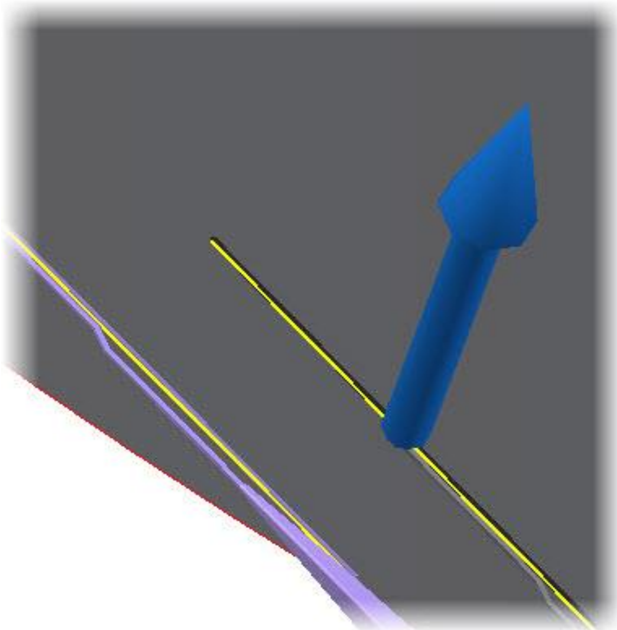


54. In the **Magnitude** dialog box, review the image. The graph is updated to reflect the cubic ramp. Click **OK**.



55. In the **Force** dialog box, click **OK**.

56. In the **Simulation Player**, click **Run** or **Replay the Simulation**. The resistive force arrow direction reverses when the wiper reverses, as shown.

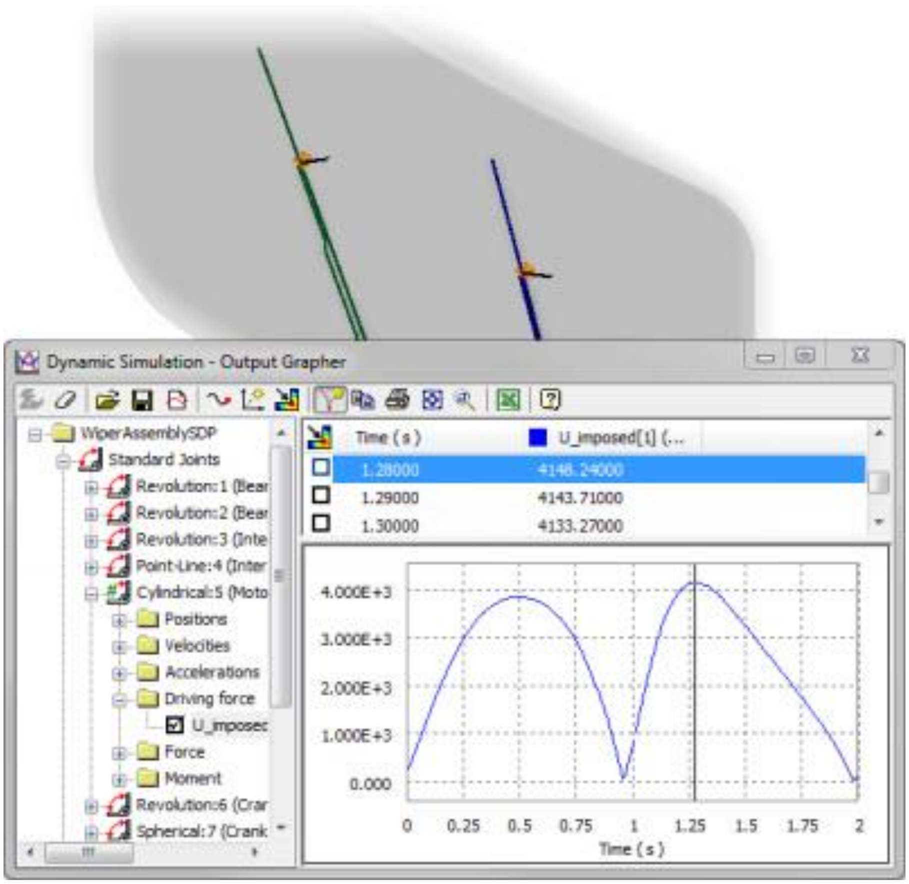


Because both wiper blades rub against the windshield, you need to repeat steps 39 through 56 for the other wiper. This is optional at this time and would be required to have a better simulation.

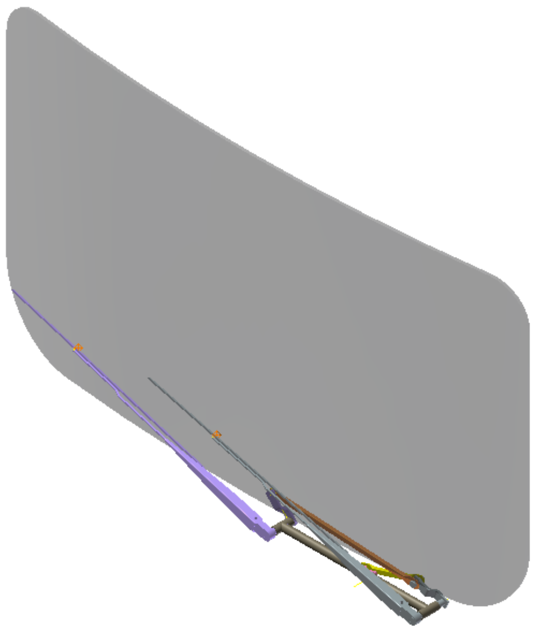
57. **Save** and close the file so you can review the simulation later if required.

1.2 Project 3B – Calculate the Drive Torque of the Wiper Assembly

Use Dynamic Simulation on the wiper assembly to calculate the driving torque required to move the wipers so that you can size the wiper motor. You then use the Output Grapher to plot the graph and review the results.



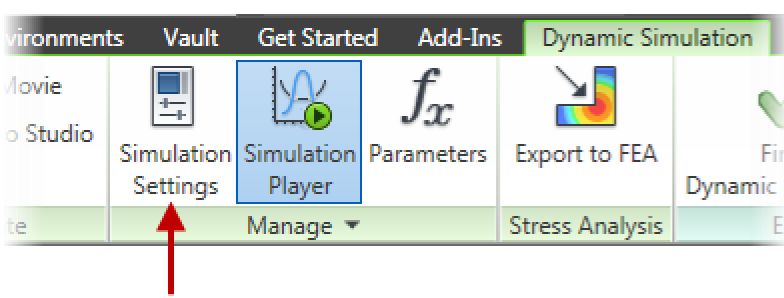
1. Open *WiperAssemblySDP.iam* Autodesk Inventor assembly file as shown below.



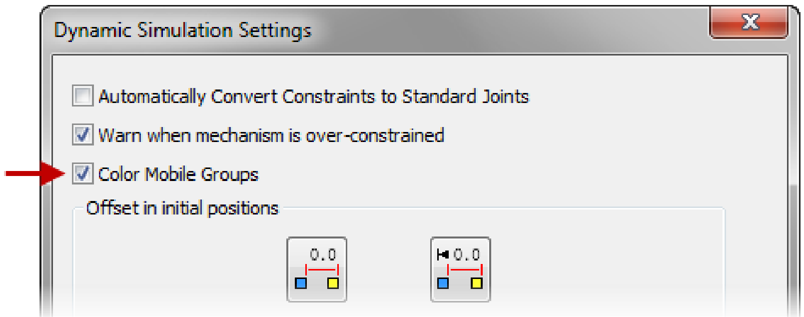
2. Click **Environments tab | Begin panel | Dynamic Simulation**.

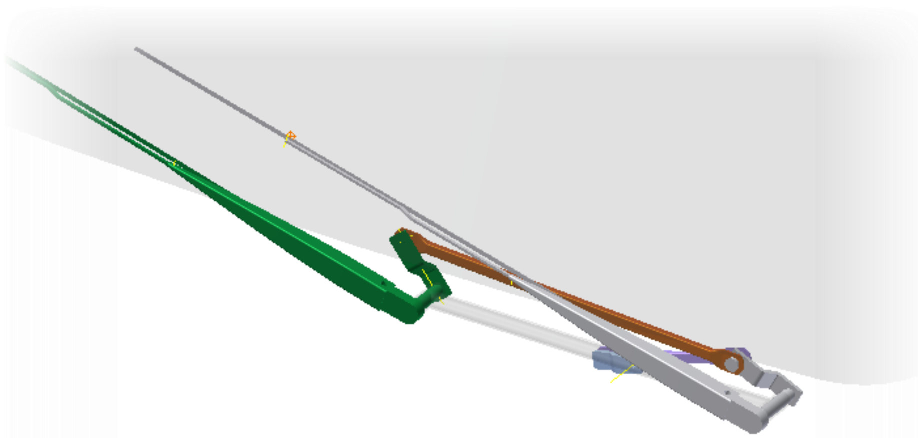
3. If you are prompted to view the tutorial, click **No** to close the window.

4. On the **Manage** panel, click **Simulation Settings**.

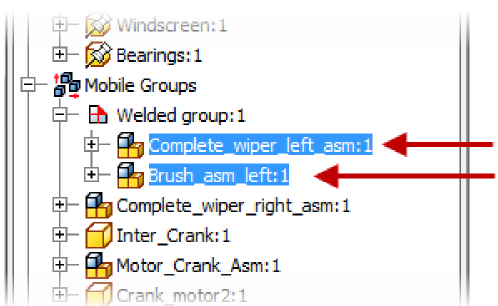


5. In the **Dynamic Simulation Settings** dialog box, select the **Color Mobile Groups** check box. This will assign a color scheme to each of the mobile groups in the assembly. This will provide a visual aid to better understand the mechanism. Click **OK**.

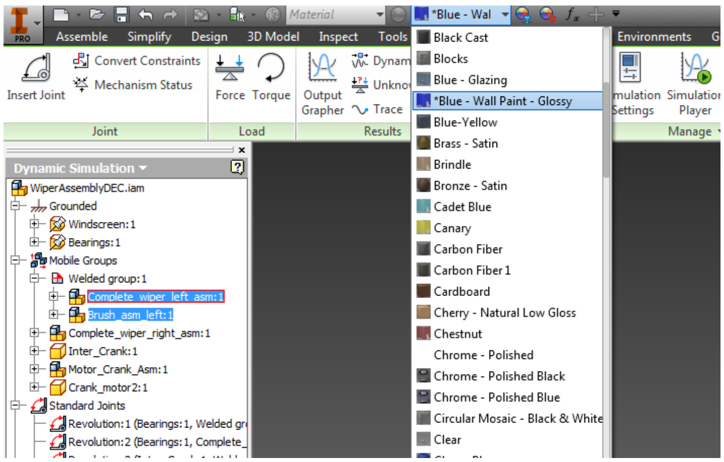




6. In the **Browser**, under **Mobile Groups**, expand *Welded group:1*. Select the two assemblies as shown below that are grouped as a welded group.



7. Select *Blue- Wall Paint- Glossy* from the **Color Override** list.

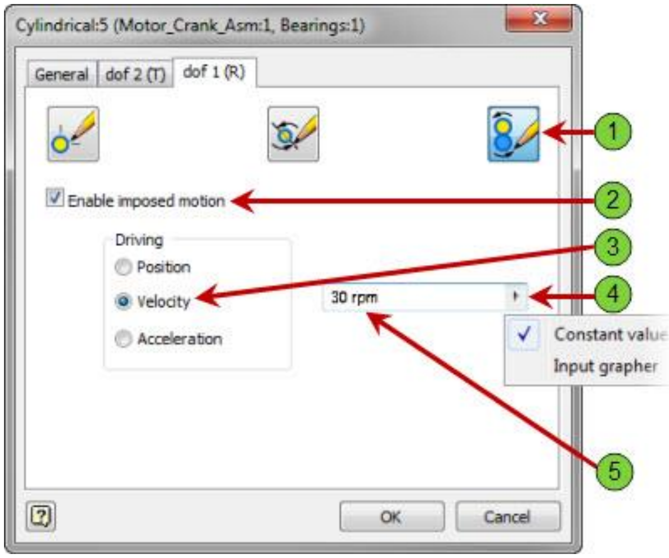


Next, you impose a velocity on the *Motor_Crank_Asm*. The mechanism is fully defined and a force of 5 N has been added to each wiper blade assembly to simulate the drag of the blade on the windshield.

8. In the **Browser**, under **Standard Joints**, right-click C*ylindrical:5 (Motor_Crank_Asm:1, Bearings:1)*. Click **Properties**.

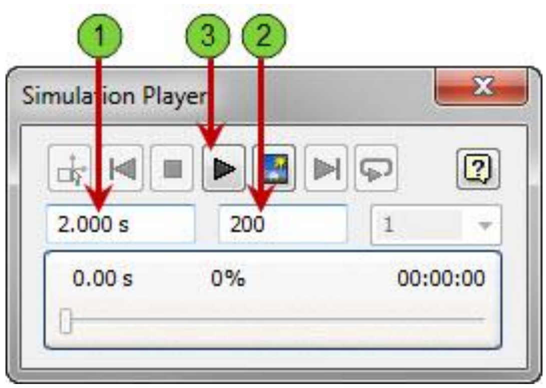
9. On the **dof 1 (R)** tab, do the following:

- Click **Edit Imposed Motion**
- Select the **Enable Imposed Motion** check box
- Under **Driving**, click **Velocity**
- Click the **Arrow** next to the edit window. Select **Constant Value** from the list
- In the edit window, type **30 rpm**
- Click **OK**



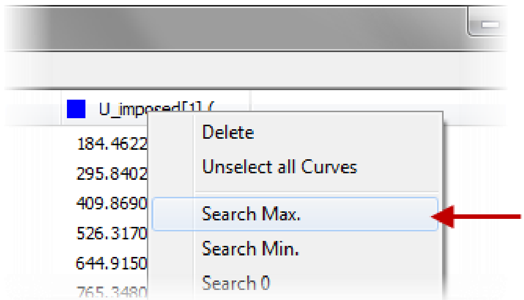
10. In the **Simulation Player**, do the following:

- For **Final Time**, type **2 s**.
- Press **TAB** on the keyboard. The **Images** value changes to **200**.
- Click **Run** or **Replay the Simulation**.



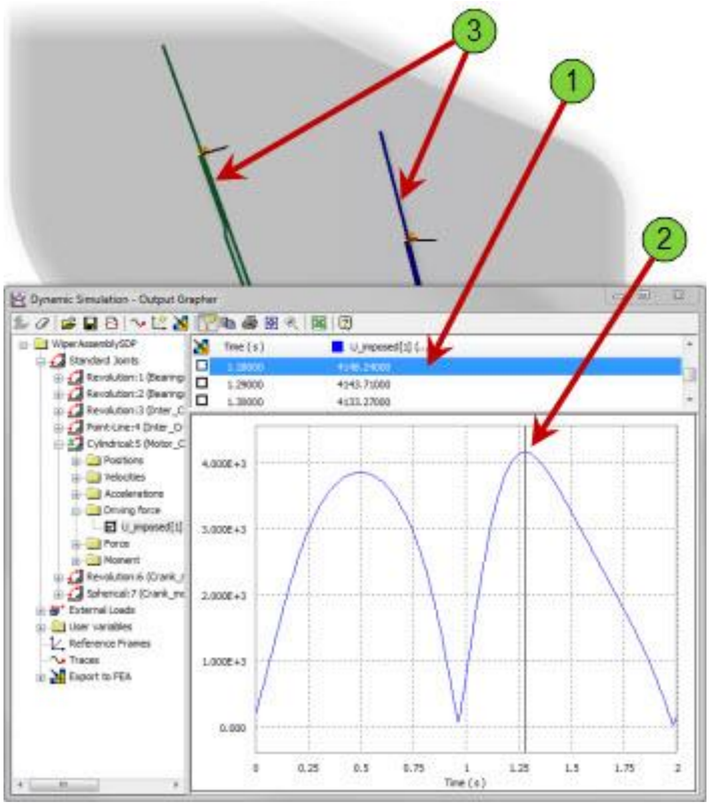
11. On the **Results** panel, click **Output Grapher**.

12. In the **Values** window, right-click in the **U_imposed** column. Click **Search Max**.

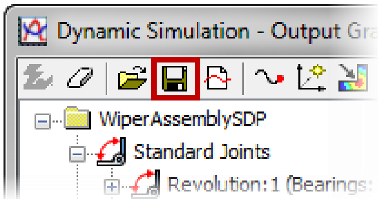


13. Review the grapher. From the results you can determine the following:

- In the **Values** window, the maximum driving torque of 4148 N mm is highlighted.
- In the graph, the time bar displays the corresponding time.
- The assembly is synchronized to the grapher, and the mechanism shows the position of the wipers at maximum drive torque.

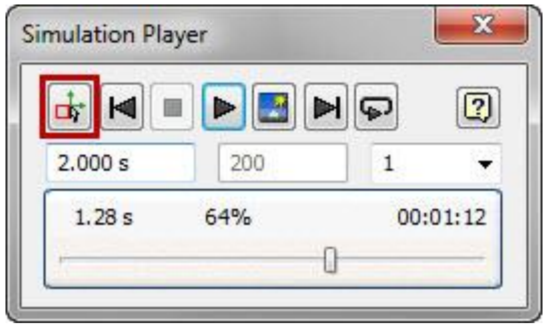


14. On the **Output Grapher** toolbar, click **Save Simulation**.



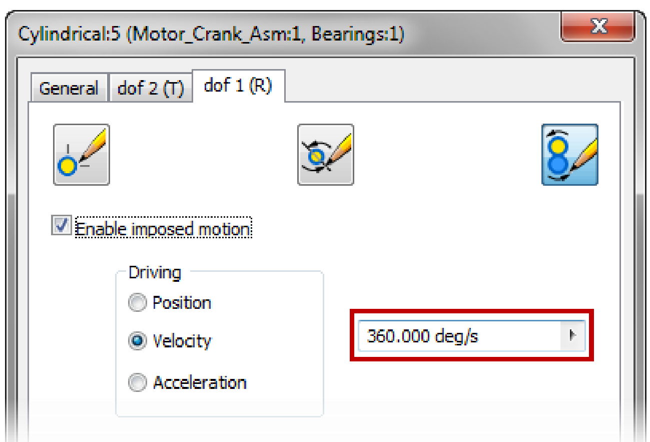
15. For file name, type **Simulation_01**. Click **Save**. This will save the current results to an external file that can later be imported back into the **Output Grapher**.

16. On the **Simulation Player**, click **Construction Mode**.



17. In the **Dynamic Simulation** browser, under **Standard Joints**, right-click *Cylindrical:5 (Motor_Crank_Asm:1, Bearings:1)*. Click **Properties**.

18. For velocity, type **360 deg/s** which is 60 rpm then click **OK**.

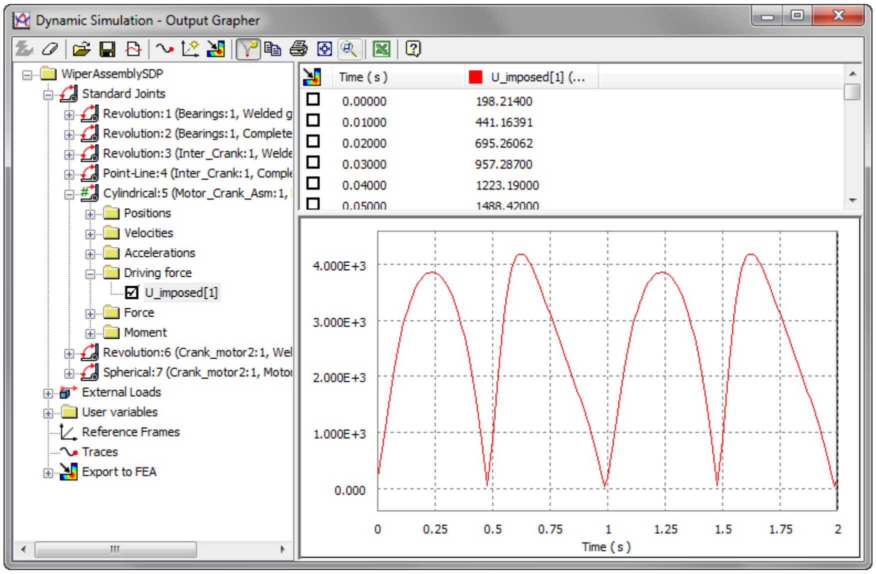


19. In the **Simulation Player**, click **Run** or **Replay the Simulation**.

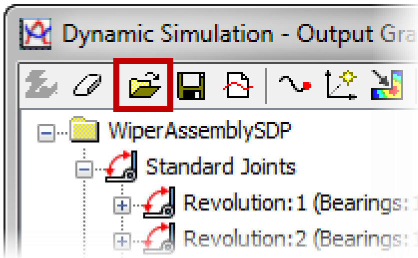
20. Right-click in the **U_imposed[1]** column. Click **Curve Properties**.

21. Change color to **Red**. Click **OK** twice.

22. The new graph in the **Output Grapher** should look like the image below.



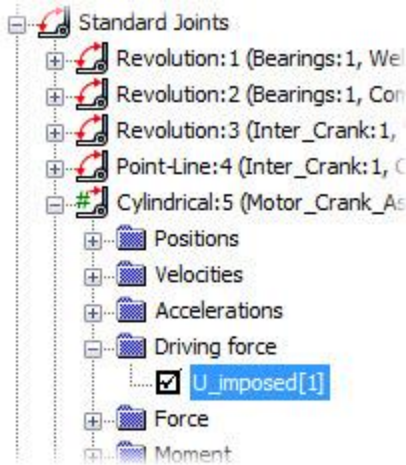
23. On the **Output Grapher** toolbar, click **Import Simulation**.



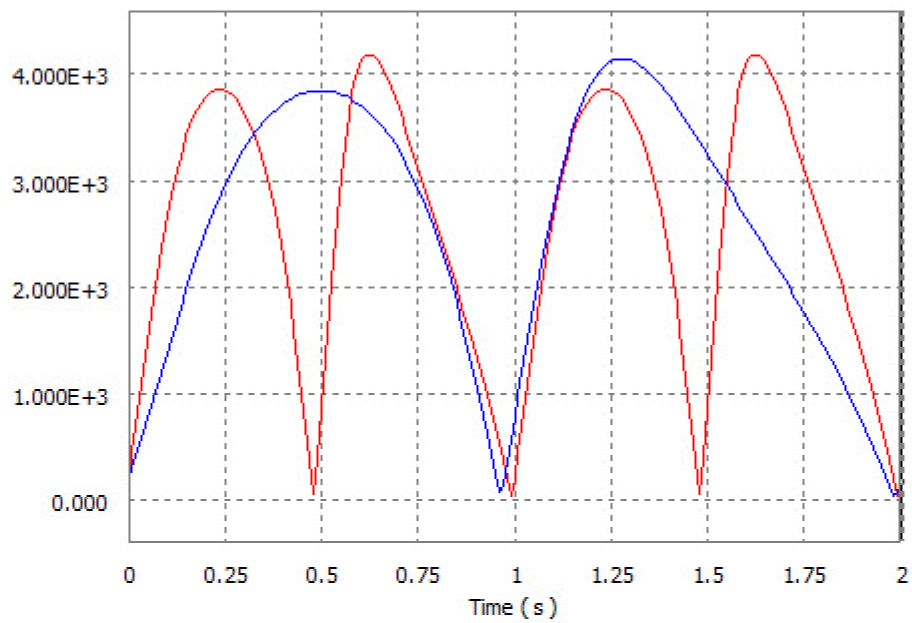
24. Open *Simulation_01.iaa* file you saved earlier in the project.

25. In the **Output Grapher** browser, expand *Simulation_01.iaa* | *Cylindrical:5 (Motor_Crank_Asm:1, Bearings:1)*.

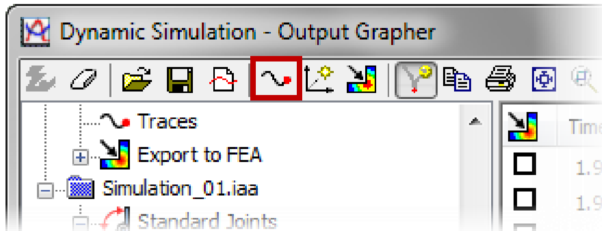
26. Under **Driving Force**, select the **U_imposed[1]** check box.



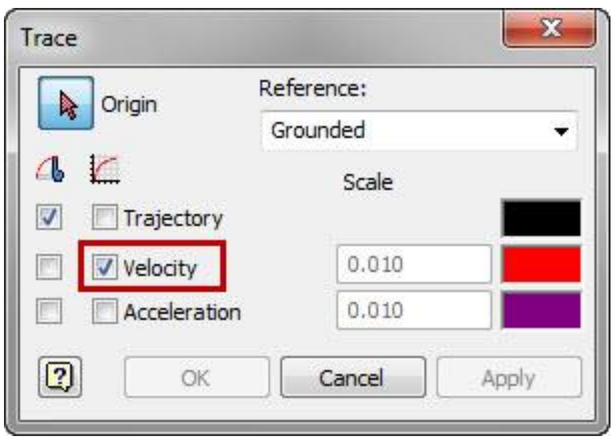
27. Review the two graphs.



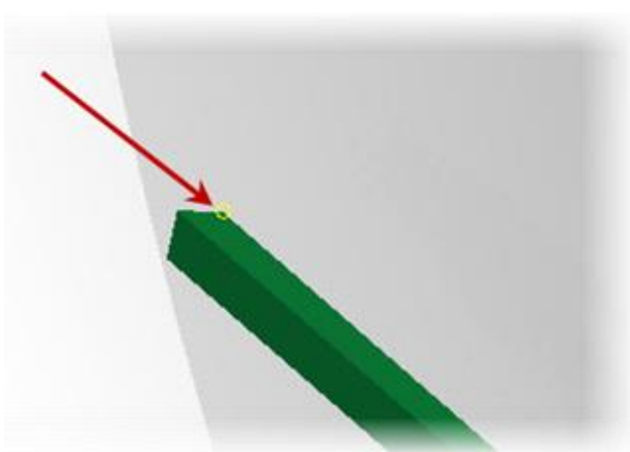
28. On the **Output Grapher** toolbar, click **Add Trace**. You can also start the **Trace** command from the **Results** panel of the ribbon menu.



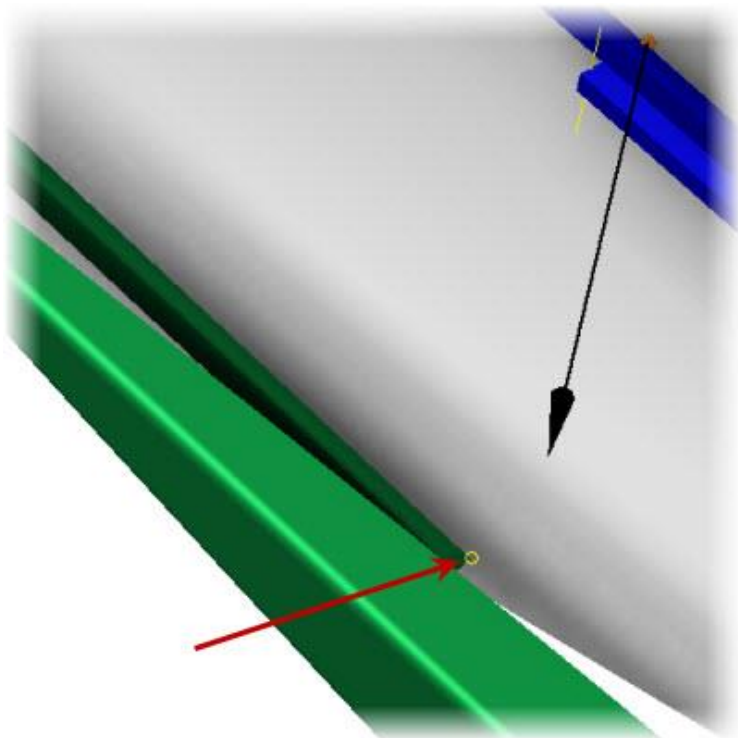
29. Select the **Velocity Display Trace** check box.



30. Select the point on the end of the wiper as shown then click **Apply**.



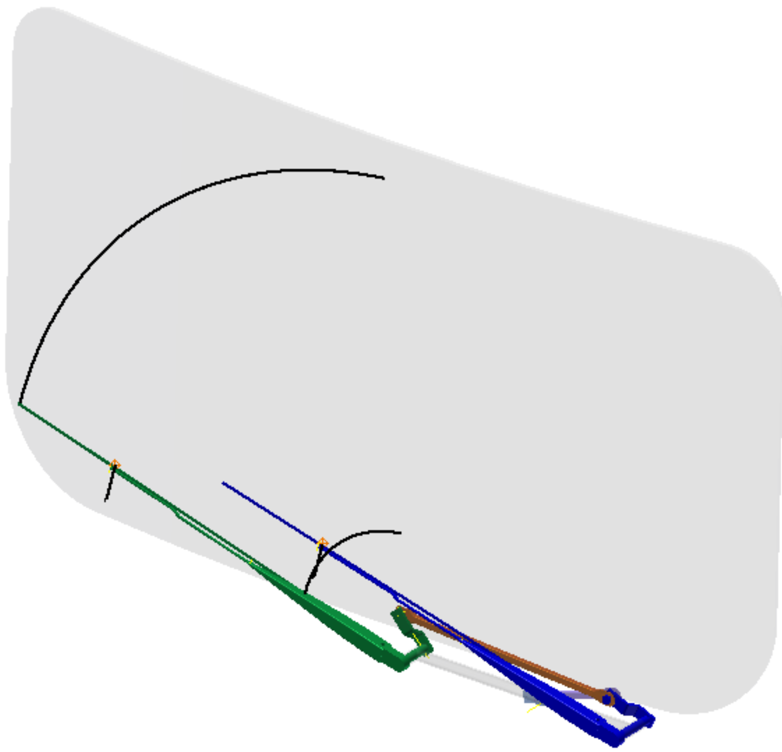
31. Select **Velocity** and then select the point at the opposite end of the wiper as shown then click **OK**.



32. On the **ViewCube**, click **Home**.

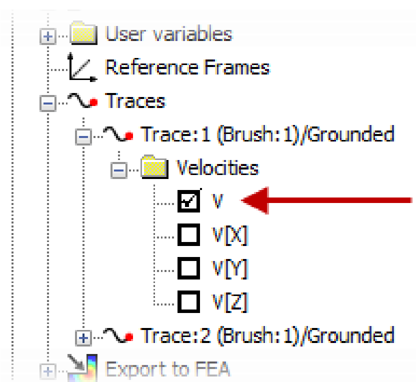
33. In the **Simulation Player**, click **Rewind** to the Beginning of the Simulation.

34. Click **Run** or **Replay Simulation**. The traces are displayed.

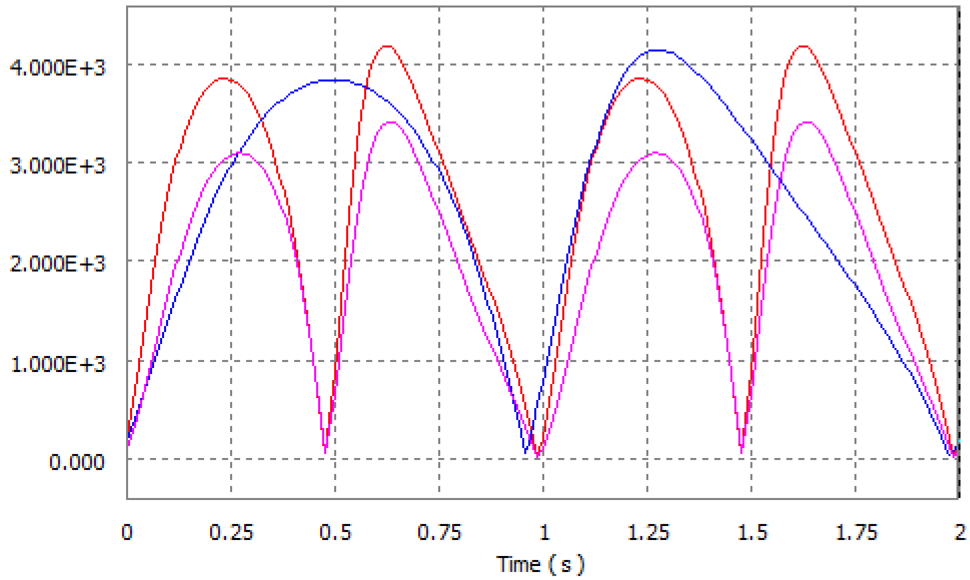


35. In the **Output Grapher** browser, expand the **Traces** folder.

36. Under *Trace:1* | **Velocities**, select the **V** check box.



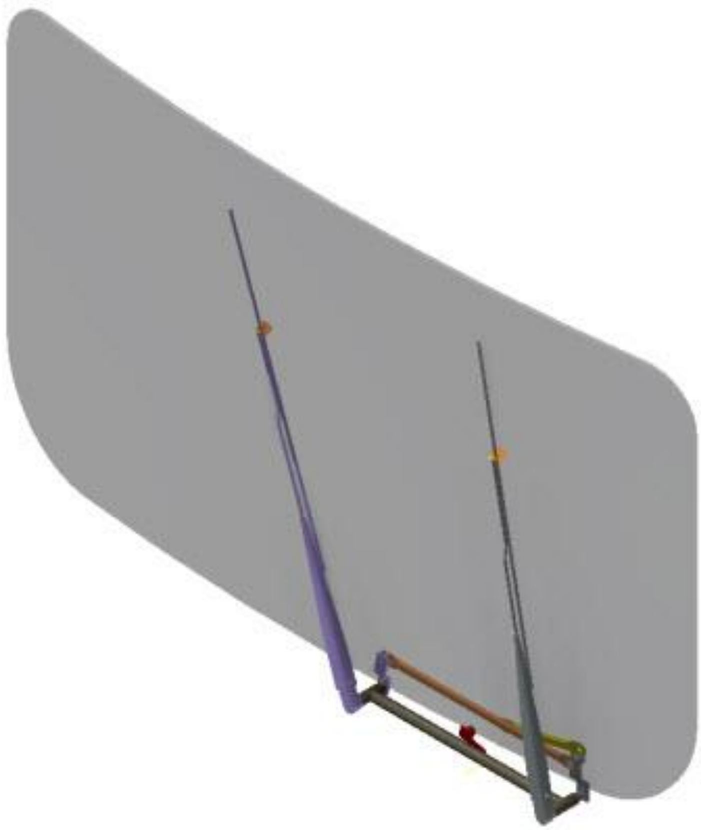
37. Review the graphs. The velocity of the point selected for the trace is displayed with the previous graphs.



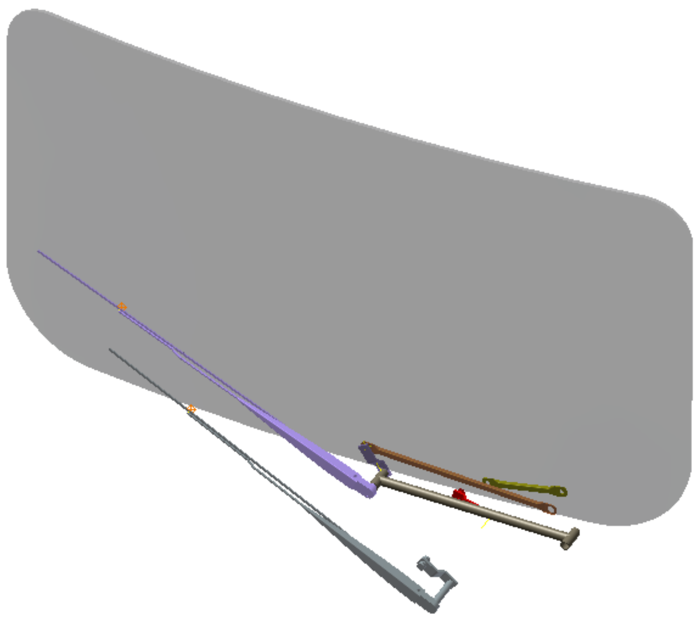
38. **Save** the file so you can review the results as required.

1.3 Project 3C – Creating a Nonredundant Model

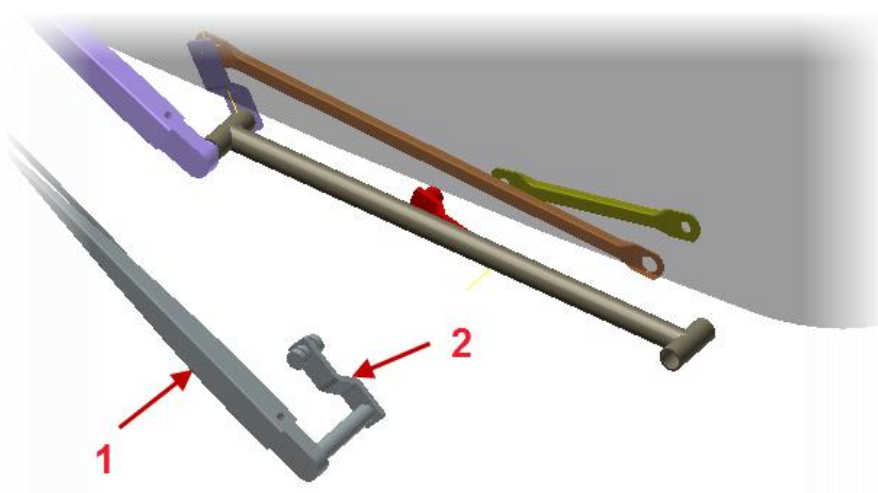
In this project, you create joints in a windshield wiper assembly. Some of the joints that you create contain redundancies. Although you can simulate a redundant model in the Dynamic Simulation environment, it is not advisable to do so. You repair the redundancies and test the joints to confirm the wiper subassembly movement.



1. In this section of the project, you create revolution joints between the wiper subassemblies and the bearings subassembly. Open the *WiperAssemblyNRM.iam* Autodesk Inventor assembly file as shown below.



2. **Zoom** in to the wiper assembly as shown. The subassemblies *Brush_asm_left* (1) and the *Complete_wiper_left_asm* (2) must move as a unit. In the next steps, you weld the two subassemblies together.

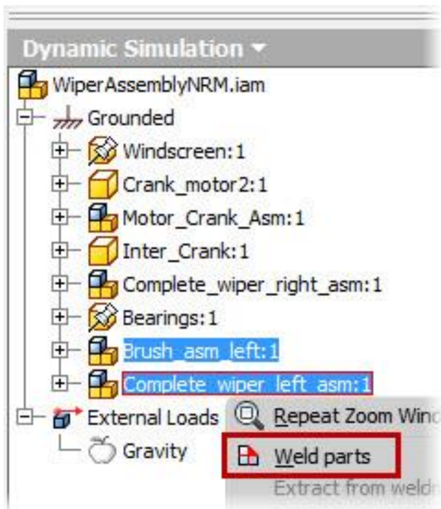


3. Click **Environments** tab | **Begin** panel | **Dynamic Simulation**.

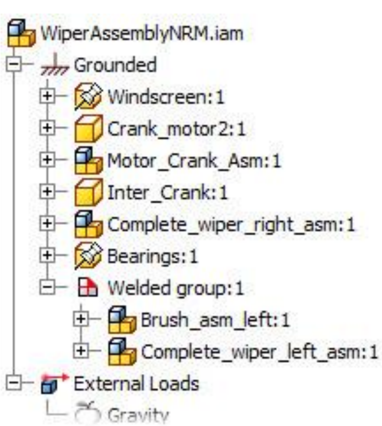
4. If you are prompted to view the tutorial, click **No** to close the window.

5. In the **Browser**:

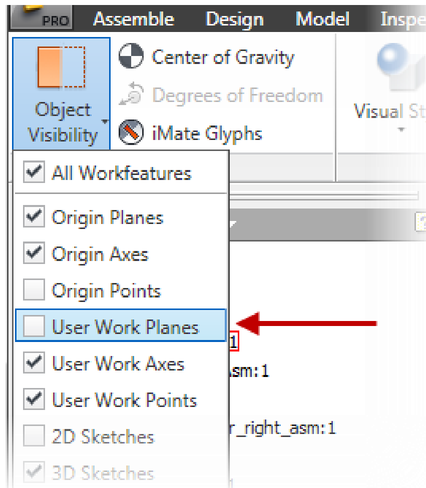
   - Select *Brush_asm_left:1* and *Complete_wiper_left_asm:1*
   - Right-click *Brush_asm_left:1*
   - Click **Weld Parts**



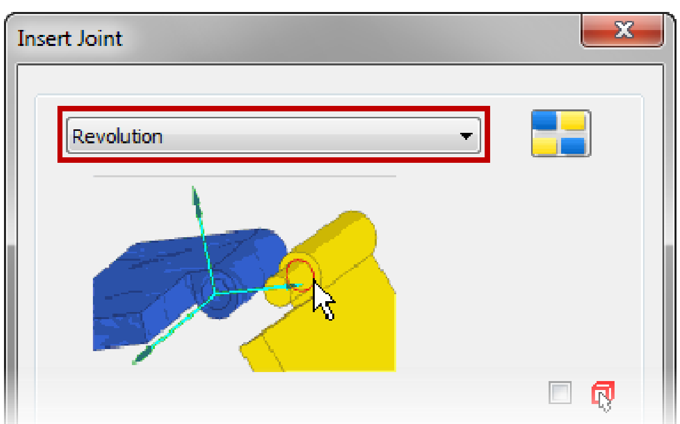
6. Review the **Browser**. A *Welded group:1* is added to the **Grounded** node. These two components will now move and act like one within the dynamic simulation environment.



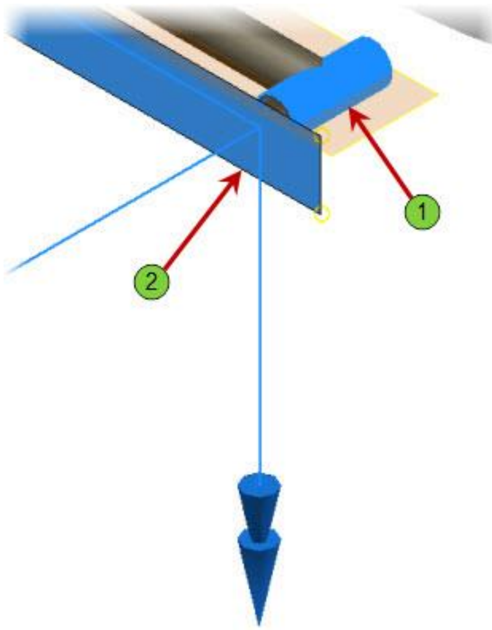
7. Click on the **View tab | Visibility panel | Object Visibility** and select **User Work Planes** to turn on the visibility of user created workplanes in the parts.



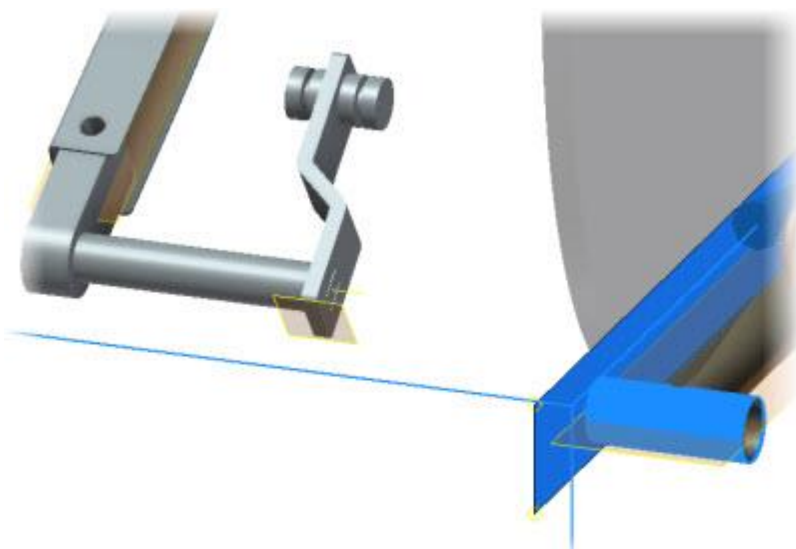
8. Click **Dynamic Simulation tab | Joint panel | Insert Joint** to start creating a new joint. Select **Revolution** as the joint type.



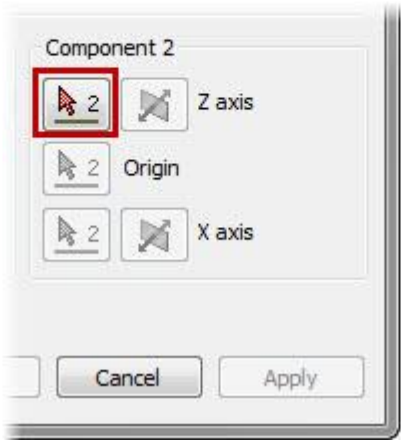
9. In the **Graphics Window**, select the tubular component (1) to set the rotation axis, and the work plane (2) to set the origin for the coordinate system, as shown.



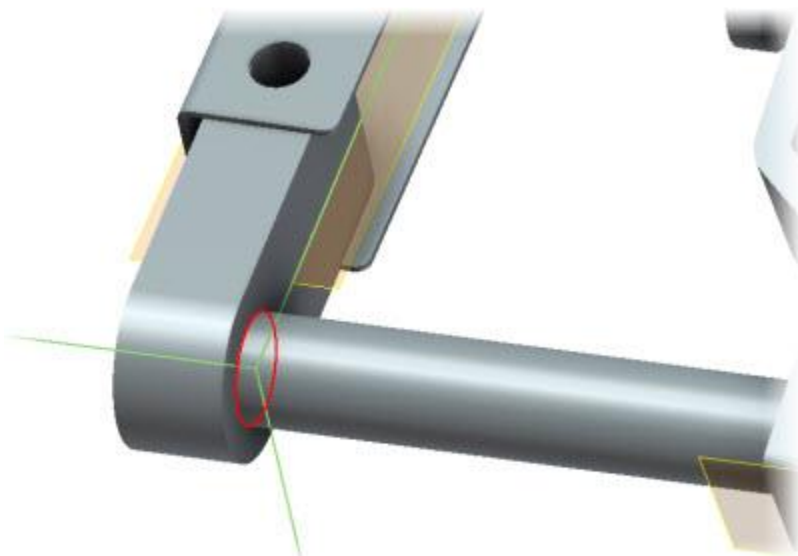
10. **Orbit** the assembly into a viewing position as shown below.



11. In the **Insert Joint** dialog box, under **Component 2**, click the **Second Selection** button.



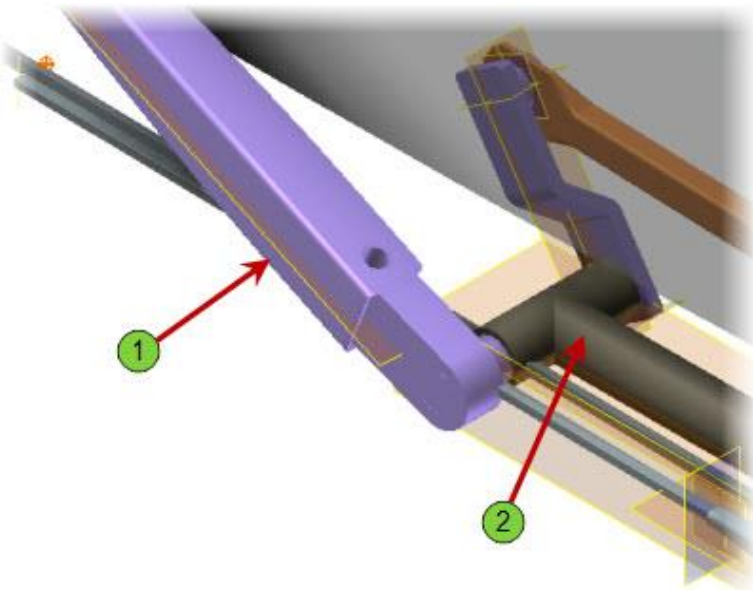
12. Click the circular edge as shown to specify the joint origin on the welded assembly.



13. Notice that the two coordinate systems are in general alignment. Click **OK** to create the joint. Now notice that the two welded group components moved into position as one single item.

14. On the **ViewCube**, click **Home**.

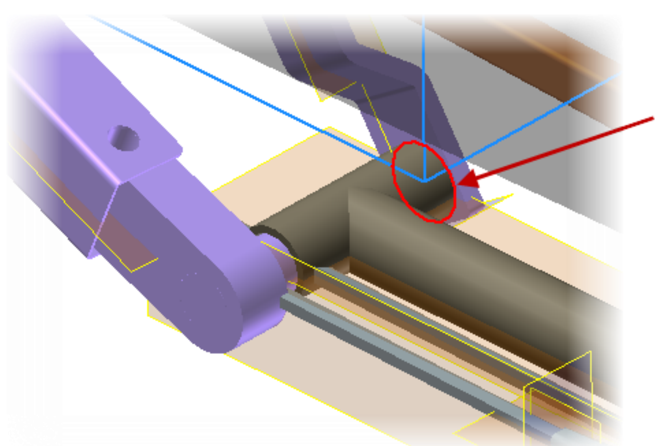
15. **Zoom** in to the assembly as shown. The *Complete_wiper_right_asm* (1) and the *Bearings* (2) subassemblies are currently in the proper orientation.



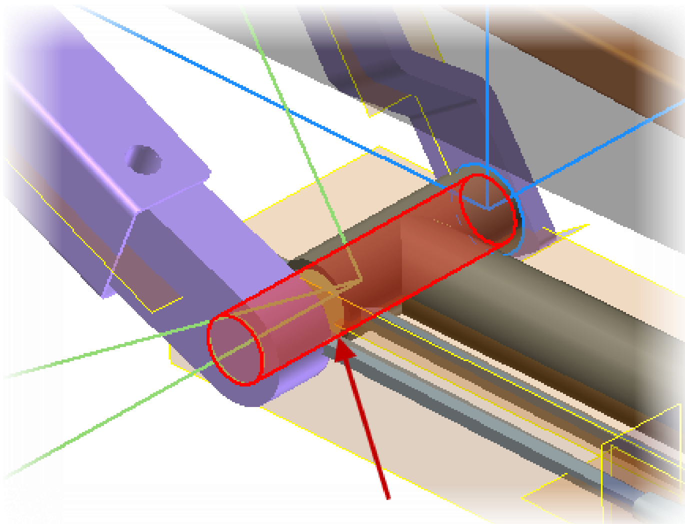
16. Now we will create a new joint between the right wiper and the bearings. Click **Insert Joint** on the Joint panel.

17. Select **Revolution** as the **Joint Type**. This will leave two DOF one rotational and transitional.

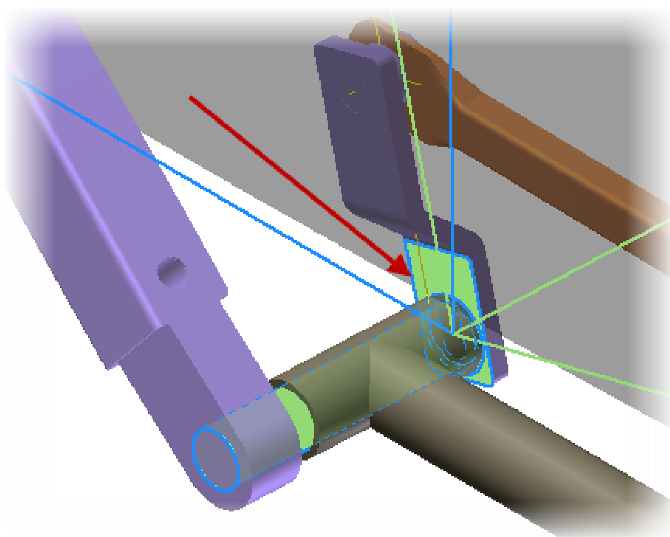
18. For **Component 1** select the outer circular edge of the bearing part as shown below.



19. For **Component 2** select the cylindrical face as shown below on the right wiper.

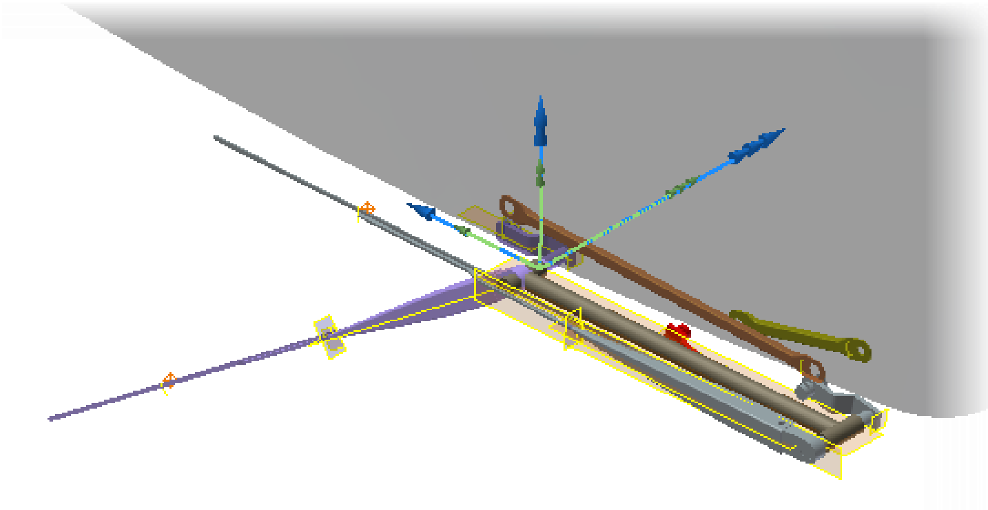


20. Select the inner face of the wiper mounting arm as shown below as the **Origin** for **Component 2**.



21. To ensure the two coordinate systems are in alignment **Flip Z Direction** on **Component 2**.

22. Click **OK** to create the revolution joint. You will notice the wiper part position moved to align the two coordinate systems as shown below.



23. To move the wiper back into the starting position right-click on the *Revolution:2* standard joint in the **Browser** and select **Properties**.

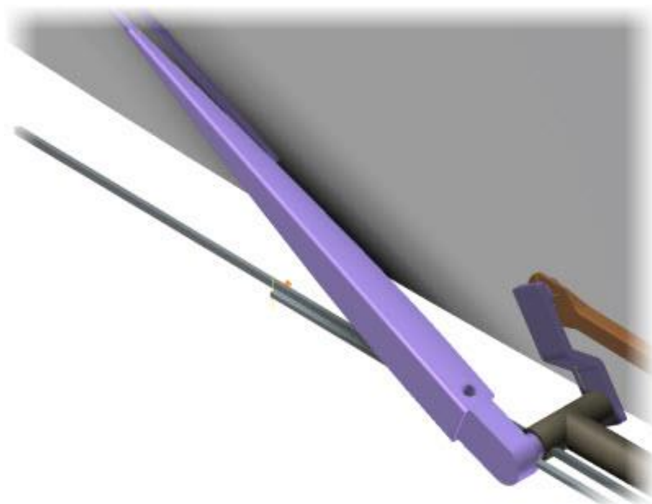
24. In the **Revolution:2** dialog complete the following:

- Click the **dof 1 (R)** tab
- Select **Edit Initial Conditions**
- For the **Position** enter **56.73 deg**
- Click **OK**

25. On the **ViewCube**, click **Home**.

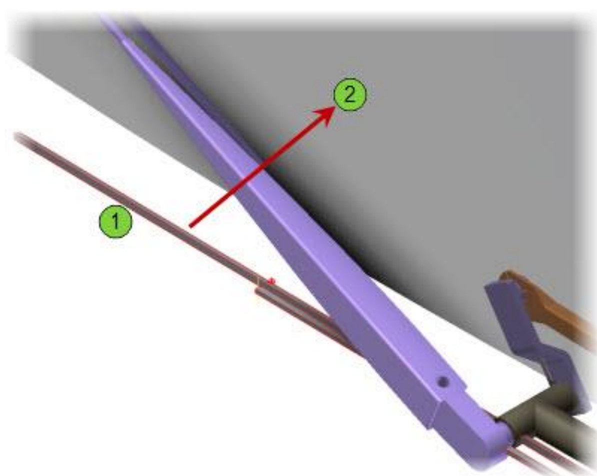
26. In this section of the project, you create revolution joints between the *Inter_Crank* and the wiper subassemblies. Using only revolution joints to build the four-bar linkage leads to redundancies. You use the **Repair Redundancies** tool to analyze and repair the problem.

- Press **ALT +]** to turn off the user work planes
- Zoom in to the wiper subassemblies, as shown

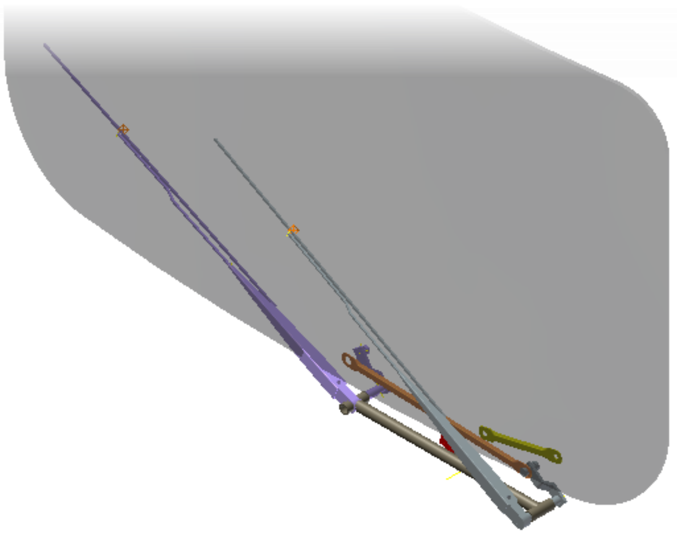


27. In the **Graphics Window**:

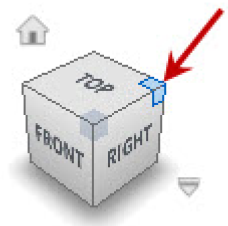
- Place you cursor over the *Complete_wiper_left_asm* as shown.
- Drag in the direction shown. This will move the component using the already created joints and is often a good method to verify your mechanism.



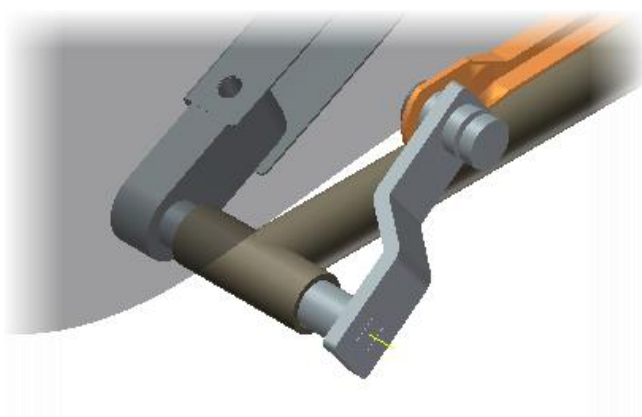
28. Position the wiper blade so that it is close to parallel to the other wiper, as shown below.



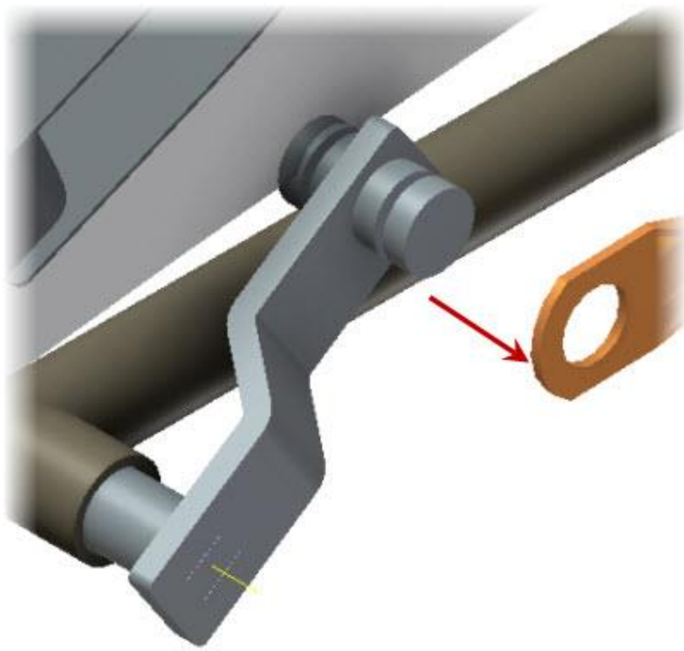
29. On the **ViewCube**, click the **TOP-RIGHT-BACK** corner.



30. Zoom in to the assembly as shown.

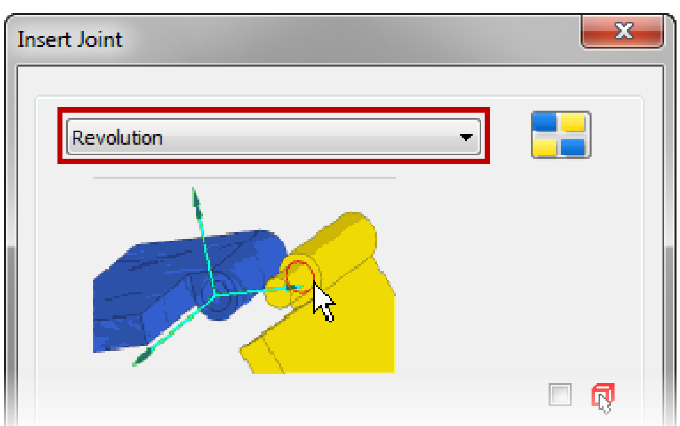


31. Drag the *Inter_Crank* to a new location, as shown. Now you create a revolution joint between the *Inter_Crank* and the *Complete_wiper_left_asm*.

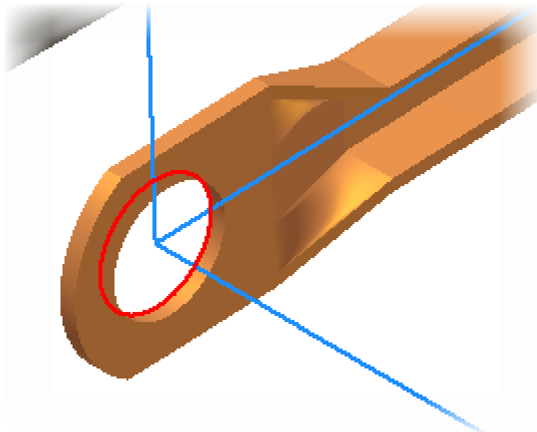


32. On the **Joint** panel, click **Insert Joint**.

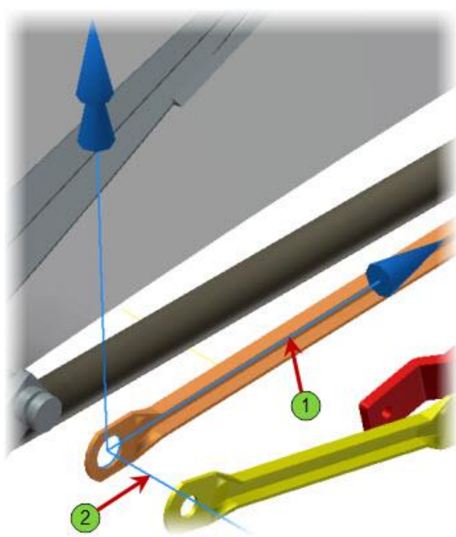
33. In the **Insert Joint** dialog box, verify that the **Revolution** joint is active.



34. Select the circular edge to set the coordinate system for the first component and its origin.

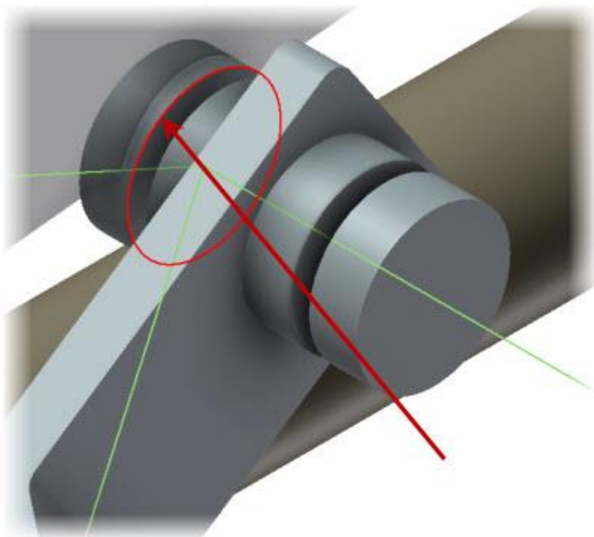


35. Review the orientation of the X axis (1) and the Z axis (2).

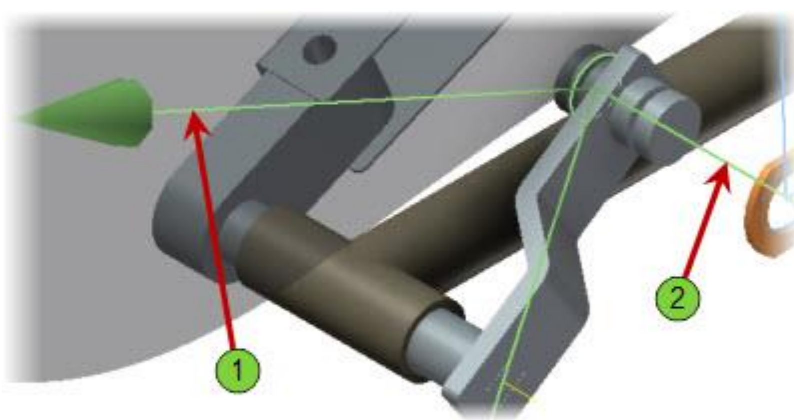


36. In the **Insert Joint** dialog box, under **Component 2**, click the **second selection** button.

37. Select the circular edge to set the coordinate system and the origin for the coordinate system. Be sure to select the exact circular edge show in the image below.

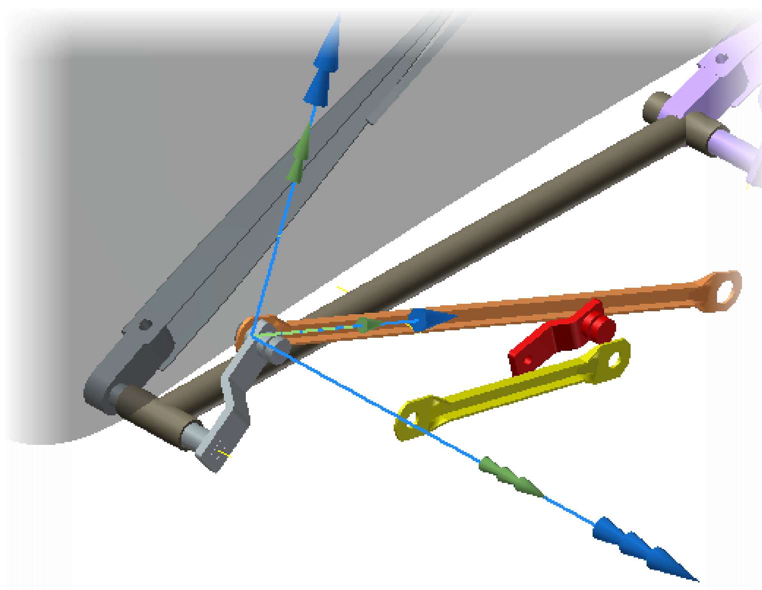


38. Review the orientation of the X axis (1) and the Z axis (2). The Z axes are pointing in the same direction, so the components maintain their current orientation. The X axes are pointing in nearly opposite directions, which will cause the Inter_Crank part to rotate so that its X axis matches the direction of the X axis on the *Complete_wiper_left_asm* subassembly. Next, you reverse the direction of the *Complete_wiper_left_asm* X axis to minimize the rotation.



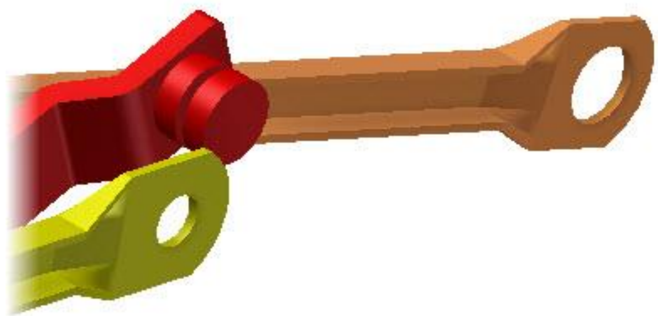
39. In the **Insert Joint** dialog box, under **Component 2**, click **Flip X Axis**. The X axis for the Complete_wiper_left_asm subassembly reverses direction.

40. Click **OK**. The joint is created. Now you create a revolution joint between the other end of the *Inter_Crank* component and the *Complete_wiper_right_asm* subassembly.

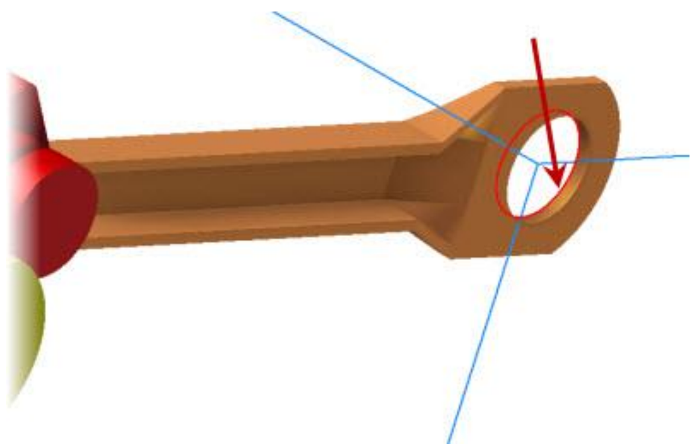


41. On the **Joint** panel, click **Insert Joint**.

42. Pan to the right as shown.

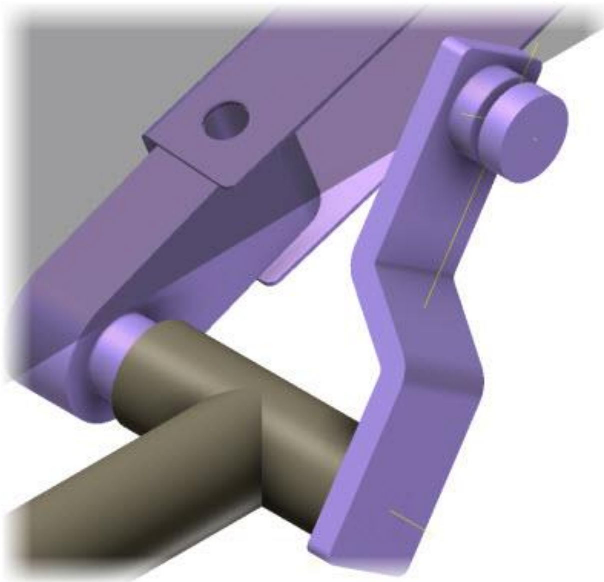


43. Select the circular edge shown in the image below to set the origin of the coordinate system for the first component. This should be the edge on the opposite side.

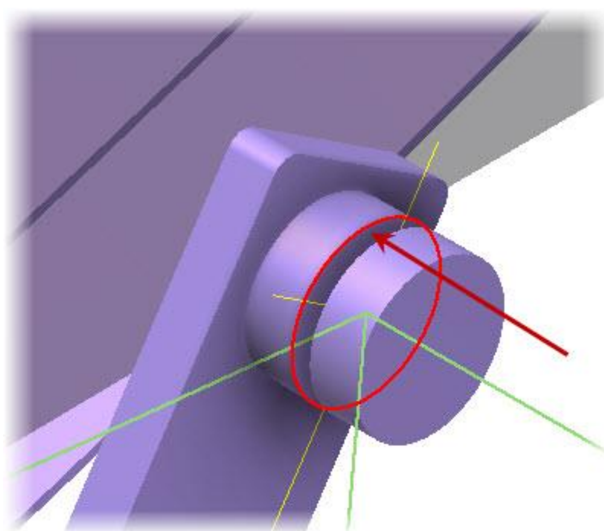


44. In the **Insert Joint** dialog box, under **Component 2**, click the **second selection** button.

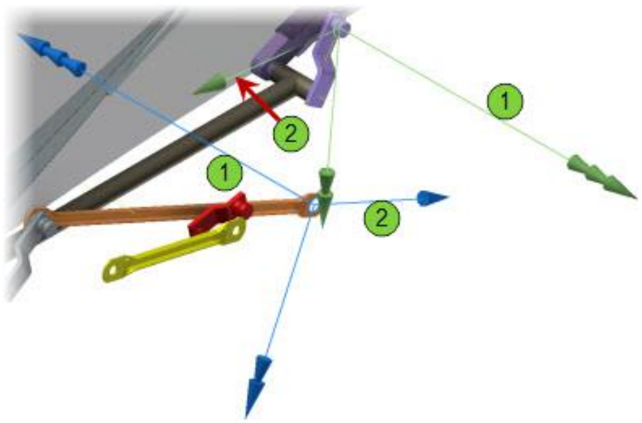
45. In the **Graphics Window**, pan over to the end of the *Complete_wiper_right_asm*, as shown.



46. Select the circular edge to set the origin of the coordinate system for the second component.

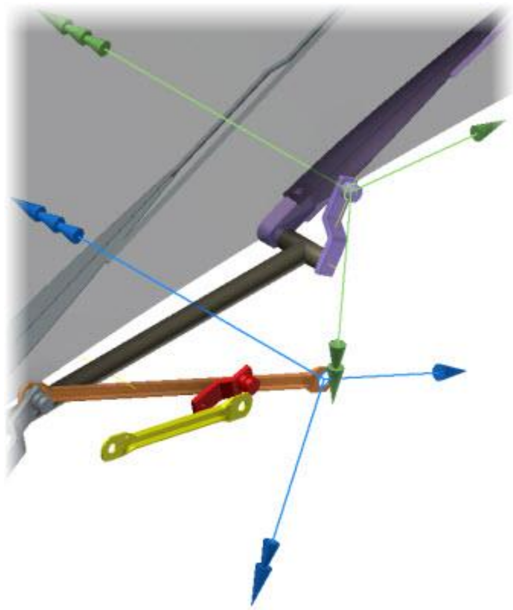


47. Review the two coordinate system axes. With the Z axes (1) and the X axes (2) for the two components pointing in opposite directions, one of the components tries to flip to match the Z axis of the other component and rotate to match the X axis, causing the joint to fail. Next, you reverse the direction of the X and Z axes of Component 2 to create a successful joint.

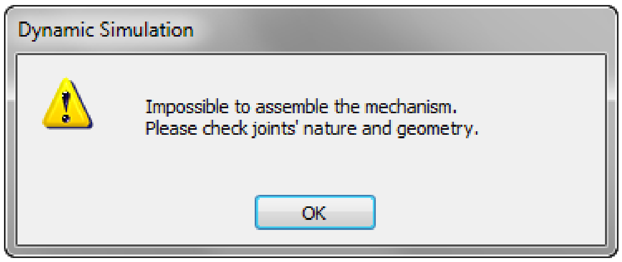


48. In the **Insert Joint** dialog box:

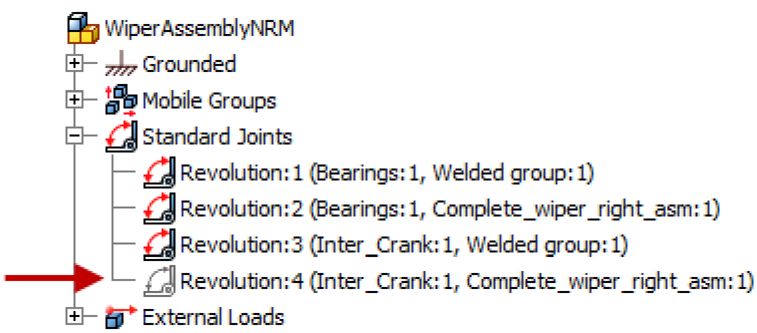
- Under **Component 2**, click **Flip Z Direction**. The Z axis reverses direction.
- Under **Component 2**, click **Flip X Direction**. The X axis reverses direction.
- Click **OK**.
- The axes should resemble the image below.



49. A warning box is displayed stating that the mechanism is impossible to assemble.
    - Click **OK** to close the warning.



50. In the browser, review the **Standard Joints** group. The *Revolution:4 (Inter_Crank:1, Complete_wiper_right_asm:1)* joint is shown with an icon indicating that it has been suppressed. Next you will repair this redundancy in the joint of being over constrained.

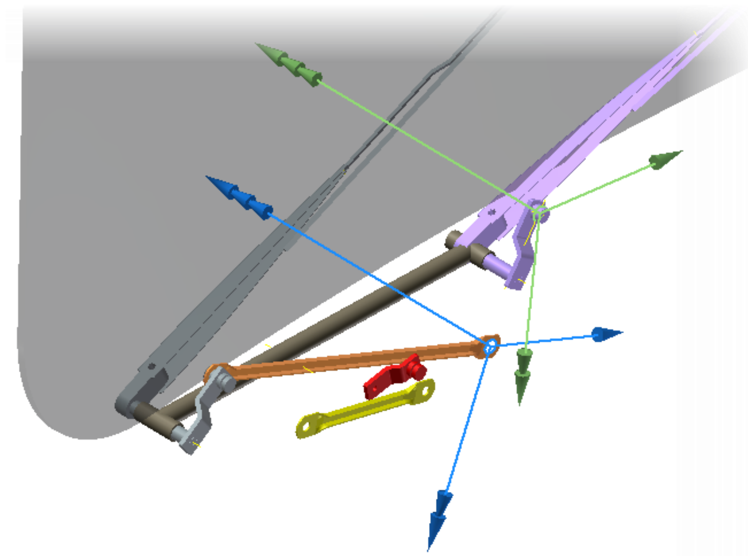


51. Delete the *Revolution:4* joint by right-clicking in the **Browser** and selecting **Delete** from the menu.

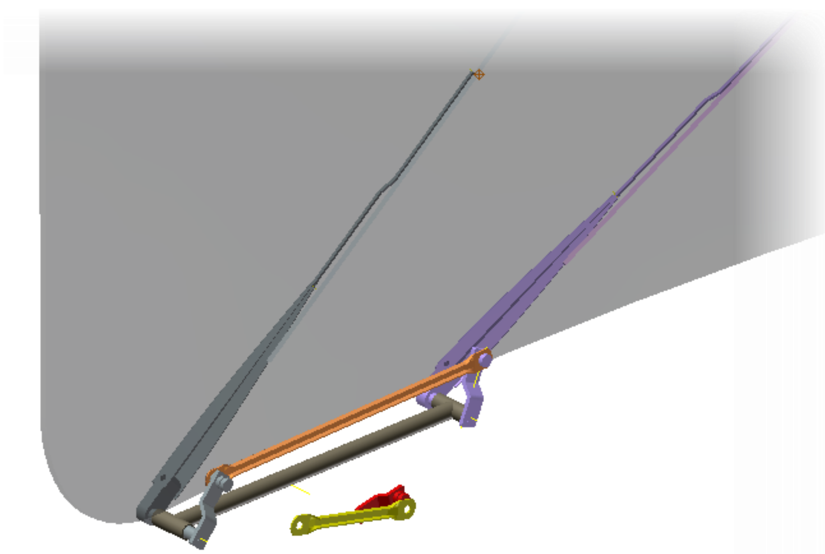
52. Now we will create a different type of joint. Click **Insert Joint** from the **Joint** panel and select **Point-Line** as the joint type.

53. Select the same geometry for **Component 1** and **Component 2** as before.

54. **Flip** the **Z axis** and **X axis** on **Component 2** to align the coordinate systems as shown below. Click **OK** to create the new joint.

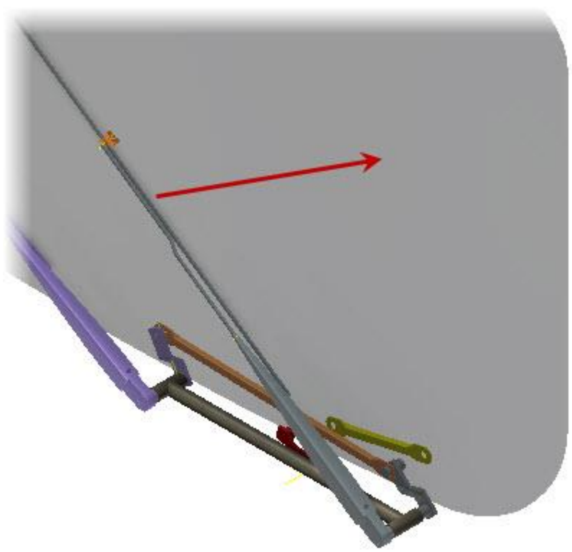


55. Now you will notice the mechanism is constrained together as shown below.

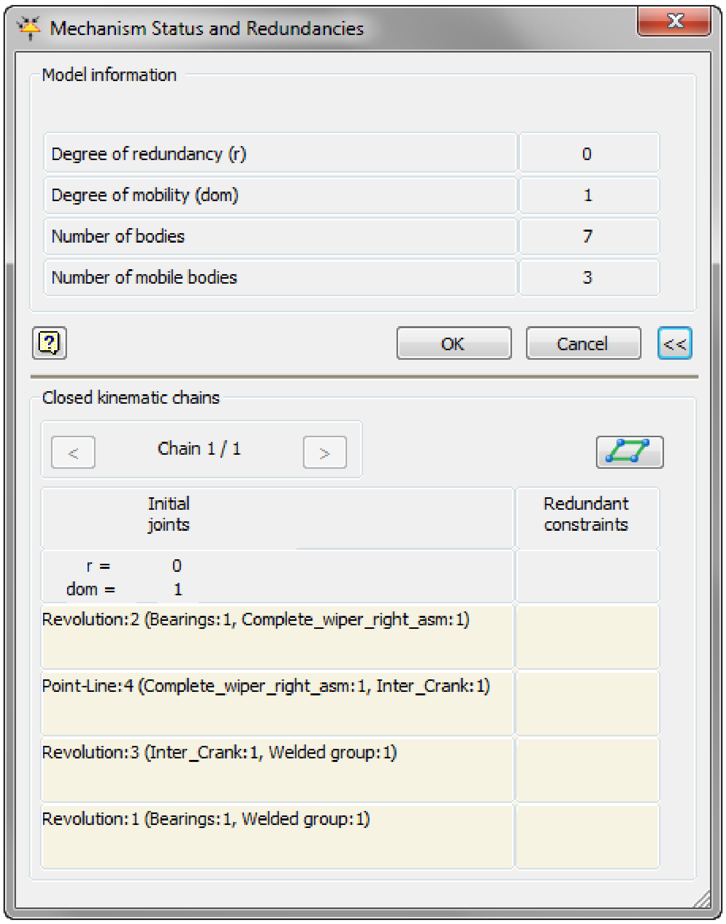


56. On the **ViewCube**, click **Home**.

57. In the **Graphics Window**, place the cursor over the either wiper blade. Click and drag to the right as shown in the image below. The wiper subassemblies are linked together through the joints you have created and move together.



58. To review the mechanism and ensure everything is constrained correct click **Mechanism Status** in the **Joint** panel.   Then click the **<<** expand button. Notice that the **Degree of Redundancy** is now 0. Within this dialog you can gain insights into issues and repair some constraint issues also if required for future projects.



59. Click **OK** to close the dialog.

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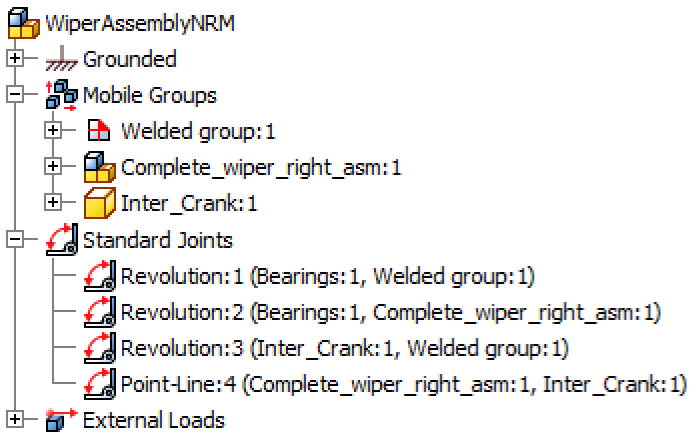
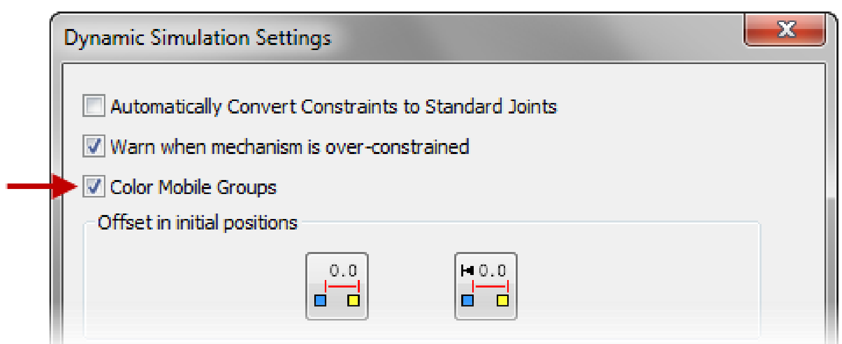
Windshield Wiper Assembly

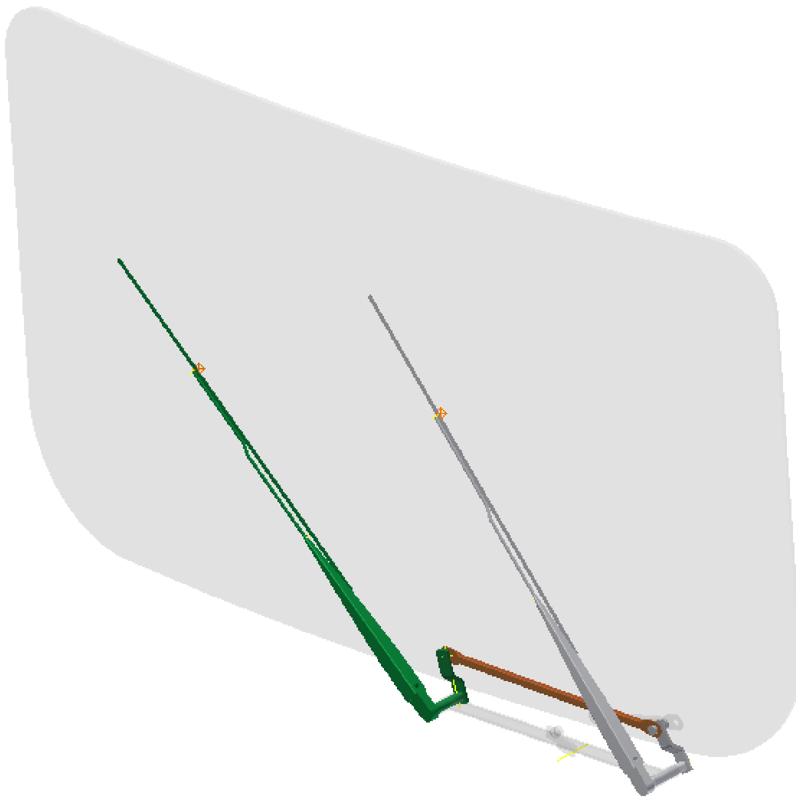
60. Notice in the Browser there are three Mobile Groups listed at the first level. These three groups of components move and operate as separate groups in the mechanism based upon the joint relationships.



61. Click **Simulation Settings** in the **Manage** panel. Check the **Color Mobile Groups** checkbox and click OK.



62. Notice how all of the components within each of the mobile groups are displayed as the same color now. This greatly helps understand the relationships and kinematics loops within your mechanism.



63. **Save** the assembly so you can review the items later if required.