Ansys Mechanical Linear and Nonlinear Dynamics

WS 09.1: Caster Wheel

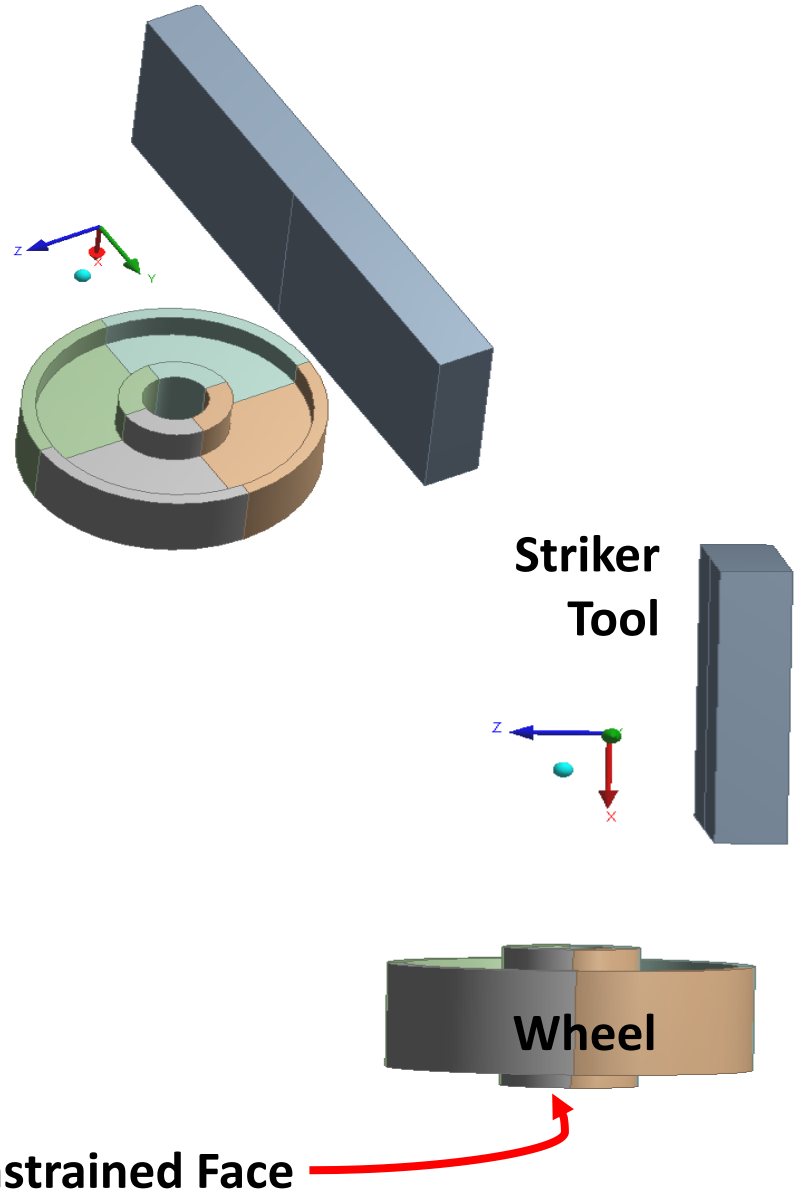
Release 2022 R2

Please note:

- These training materials were developed and tested in Ansys Release 2022 R2. Although they are expected to behave similarly in later releases, this has not been tested and is not guaranteed.
- The screen images included with these training materials may vary from the visual appearance of a local software session.
- Although some workshop files may open successfully in previous releases, backward compatibility is somewhat unlikely and is not guaranteed.

Workshop 09.1 - Goals

- Our goal is to determine the dynamic response of a caster wheel exposed to a side impact such as hitting a curb.
- This may be simulated in a physical test by dropping a heavy Striker Tool on the side of the wheel.
  - The dropped weight represents side impact on the wheel.
- The Wheel and Striker Tool are made of Steel.
  - Assume the far face of the Wheel/Axle is constrained.
  - Assume the sides of the Striker are constrained to slide up and down vertical rails.

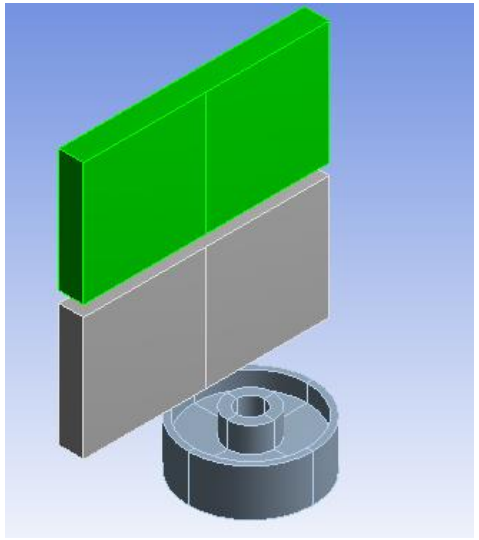


Workshop 09.1 - Project Schematic

- Start a new Workbench session and insert a Transient Structural system.
- Import Geometry file “caster_test2.stp”
- Edit the Model cell to open the Mechanical application.
  - verify that the material assignment is Structural Steel for all parts
- In Mechanical, set the units system as follows:
  - Metric (m, kg, N, s, V, A)
  - Degrees
  - RPM
  - Celsius

Workshop 09.1 – Preprocessing – Contacting Bodies

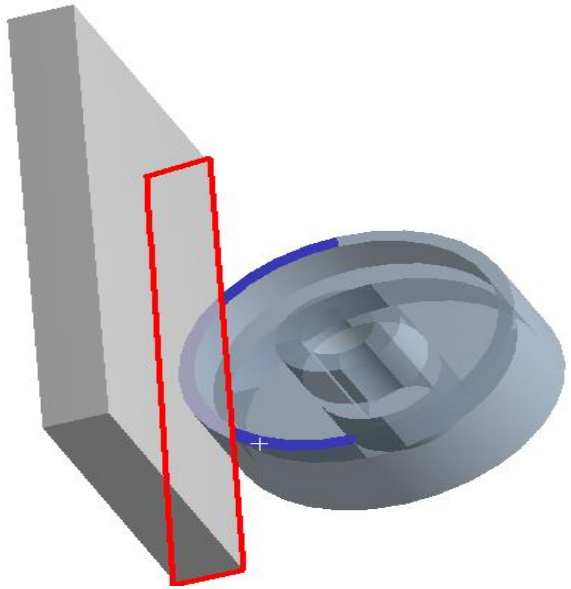
- The geometry model consists of two Striker bodies. Only one is required, so suppress the upper Striker:
  - We will incorporate the lower Striker in the simulation only.
  - It is customary when simulating impacting bodies to position the bodies so that they are close to touching. Then an initial velocity is applied to the lower Striker to account for its momentum due to the drop height & force.



Suppress upper Striker

Workshop 09.1 – Preprocessing - Contacts

- There is a small initial gap between the Striker and the Caster Wheel, therefore no contact was detected between those bodies.
- Define Frictionless contact between the bottom face of the Striker Tool and the top face of the Caster Wheel.
  - Leave all contact settings at the defaults

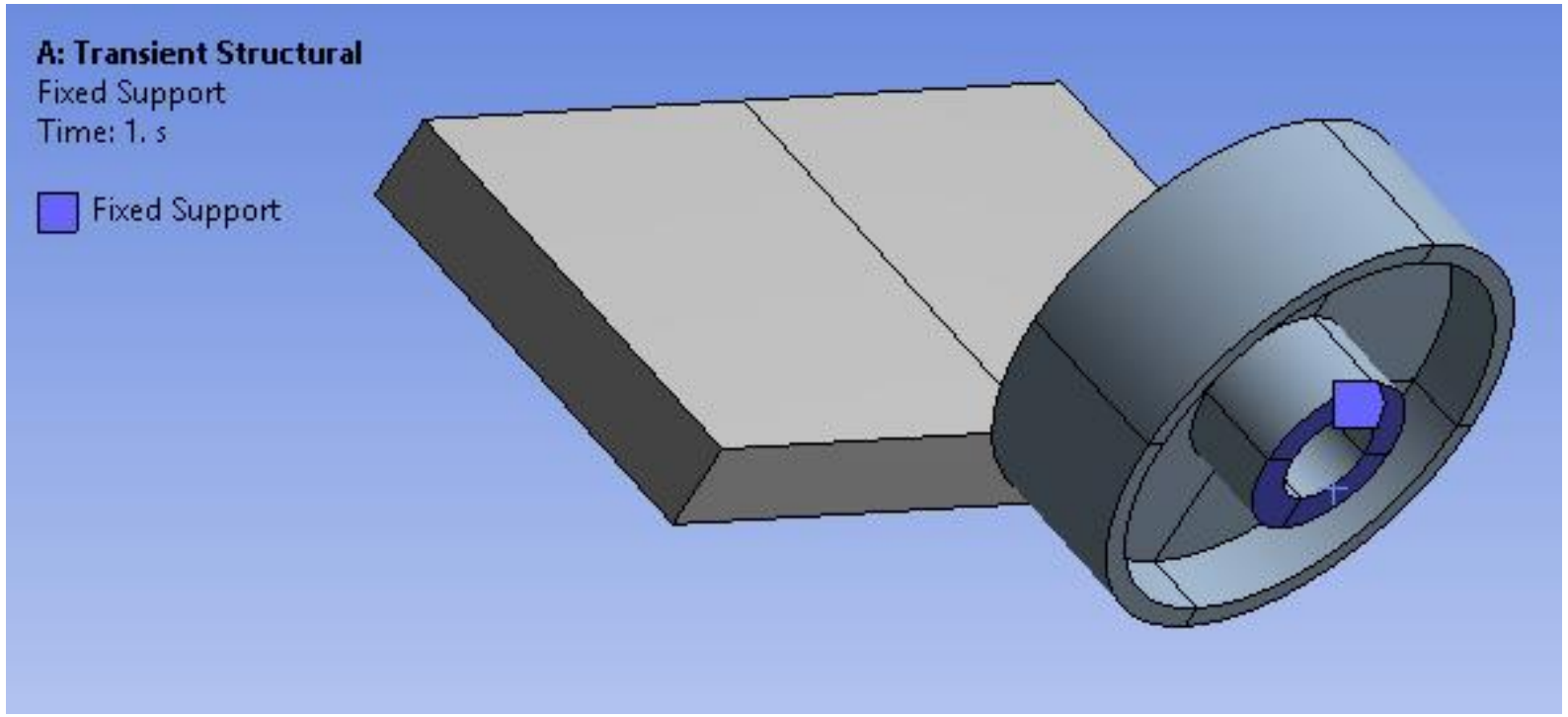


Details of "Frictionless - caster_test2-FreeParts|1 To cast

Scope	
Scoping Method	Geometry Selection
Contact	1 Face
Target	2 Faces
Contact Bodies	caster_test2-FreeParts|1
Target Bodies	caster_test2-FreeParts|2
Protected	No
Definition	
Type	Frictionless
Scope Mode	Manual

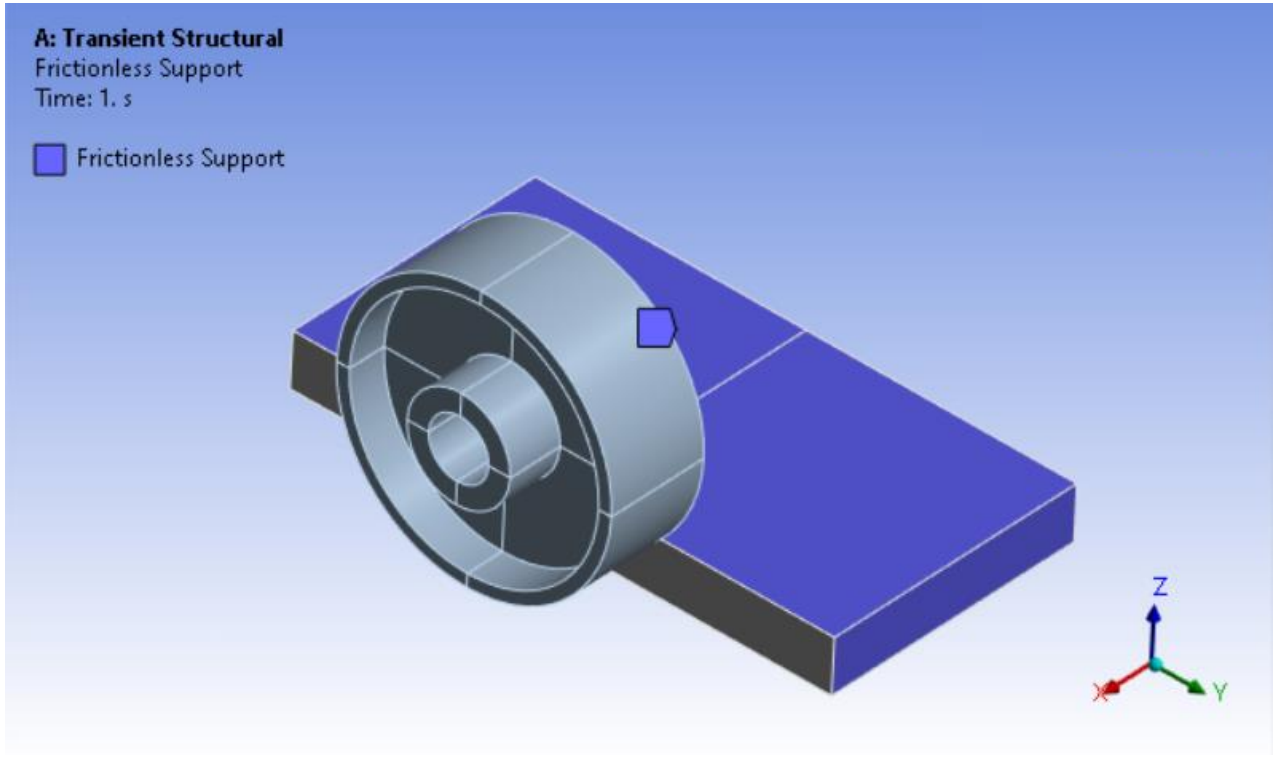
Workshop 09.1 – Environment - Supports

- Apply a Fixed Support to the opposite side of the Caster Wheel bore to oppose loads on the wheel.



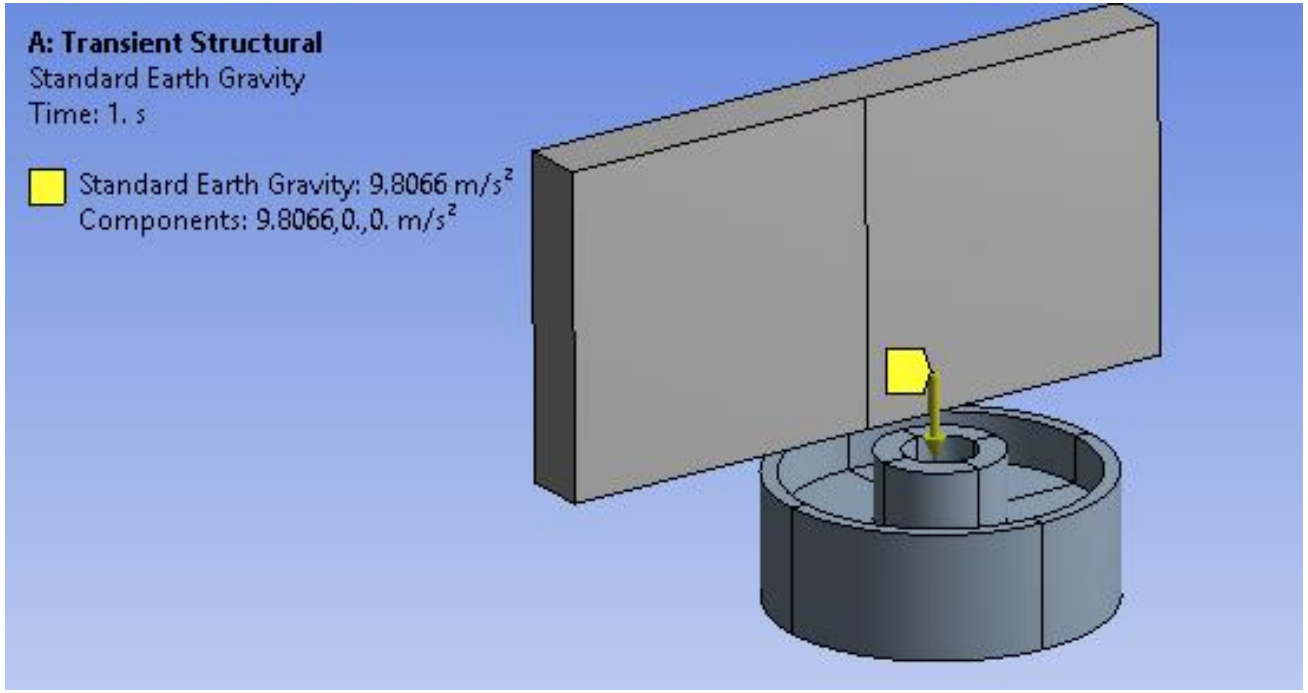
Workshop 09.1 – Environment - Supports

- The Striker Tool is guided on rails so it can only travel up and down (X direction in this model) when dropped on the wheel.
  - Use a Frictionless Support on the three faces shown to achieve this effect.



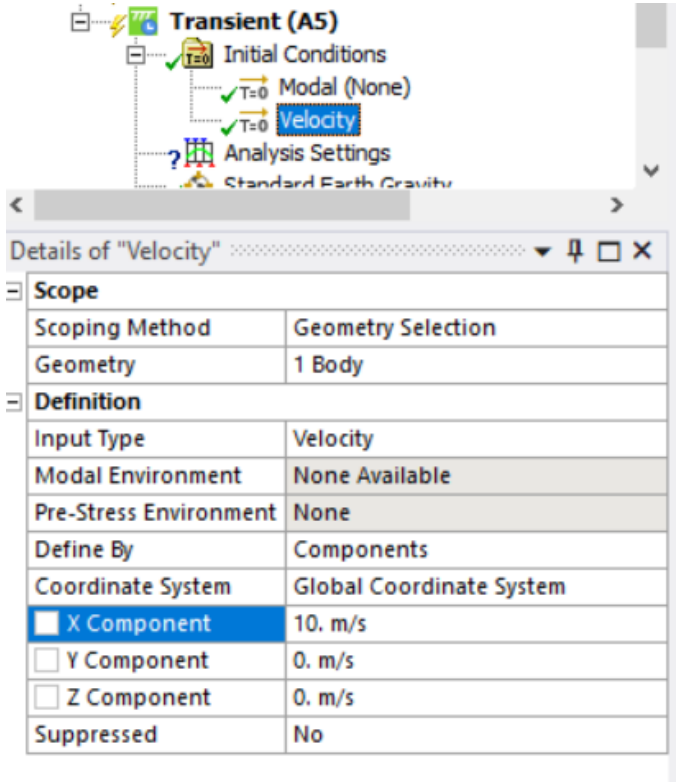
Workshop 09.1 – Environment – Gravity

- Although the Striker impact will be modeled using an Initial Velocity applied to the Striker, it's customary to also include gravity to account for the mass of the Striker, especially if it's desired to carry the simulation out long enough to include rebound and/or additional impacts beyond rebound.
  - Insert Standard Earth Gravity in the +X direction.



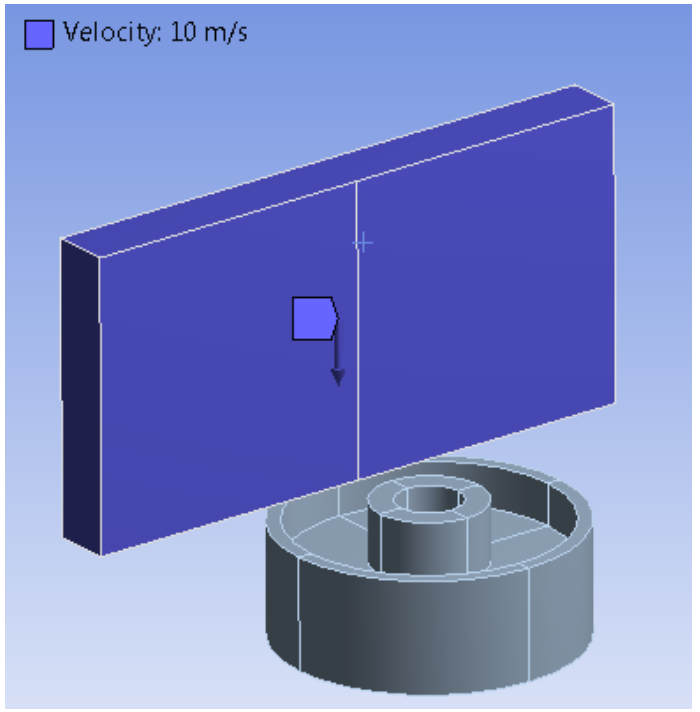
Workshop 09.1 – Environment – Initial Velocity

- Apply an initial velocity on the Striker from the Initial Conditions branch of the model outline.
  - Apply 10 m/s in the +X direction
  - This is equivalent to a drop height of approximately 5 m (using $Vo = \sqrt{(2gh)}$)



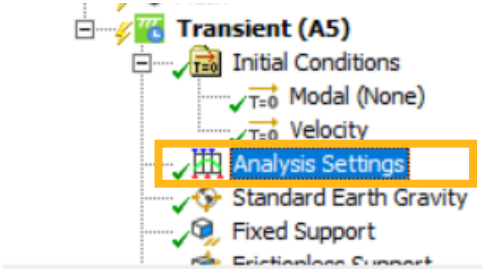
Details of "Velocity"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Input Type	Velocity
Modal Environment	None Available
Pre-Stress Environment	None
Define By	Components
Coordinate System	Global Coordinate System
X Component	10. m/s
Y Component	0. m/s
Z Component	0. m/s
Suppressed	No



Workshop 09.1 - Solution Settings – Time Steps

- Select the Analysis Settings branch and define the End Time and Time Step sizes as shown
  - It may take additional calculations and/or trial & error to find values that are appropriate for the scale and severity of your non-linear problem.
  - Some items to consider:
    - Is the Step End Time long enough to capture the full impact event and/or any subsequent impacts if they are of interest?
    - Is the minimum step size sufficient to allow convergence, but also to accurately capture any peak responses throughout the impact?
- Solve the Transient analysis.

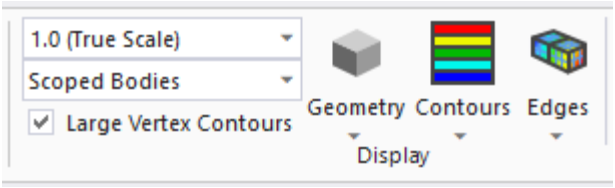


Details of "Analysis Settings"

Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1.e-003 s
Auto Time Stepping	On
Define By	Time
Initial Time Step	1.e-004 s
Minimum Time Step	3.e-005 s
Maximum Time Step	2.e-004 s
Time Integration	On
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Large Deflection	On
App. Based Settings	Moderate Speed Dynamics
Restart Controls	
Nonlinear Controls	
Advanced	
Output Controls	
Damping Controls	
Analysis Data Management	
Visibility	

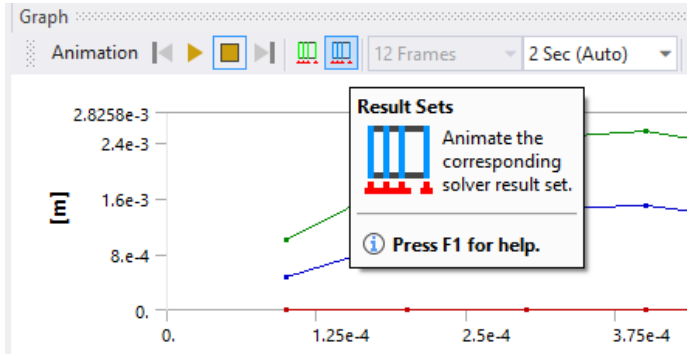
Workshop 09.1 - Results

- After the Solution is completed review the results.
  - Use a Total Deformation result to ensure that the Striker makes full contact and at least begins its rebound.
  - Use an Equivalent Stress result scoped to the Caster Wheel to ensure that any peak stresses are accurately captured.
- Very important in many problems like this …
  - Set Displacement Scaling to “1.0 (True Scale)”

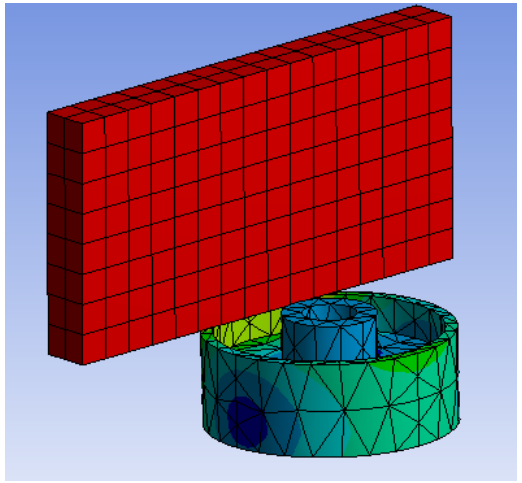


Note: your result magnitudes may vary slightly throughout this workshop due to mesh and software release differences

Workshop 09.1 - Results

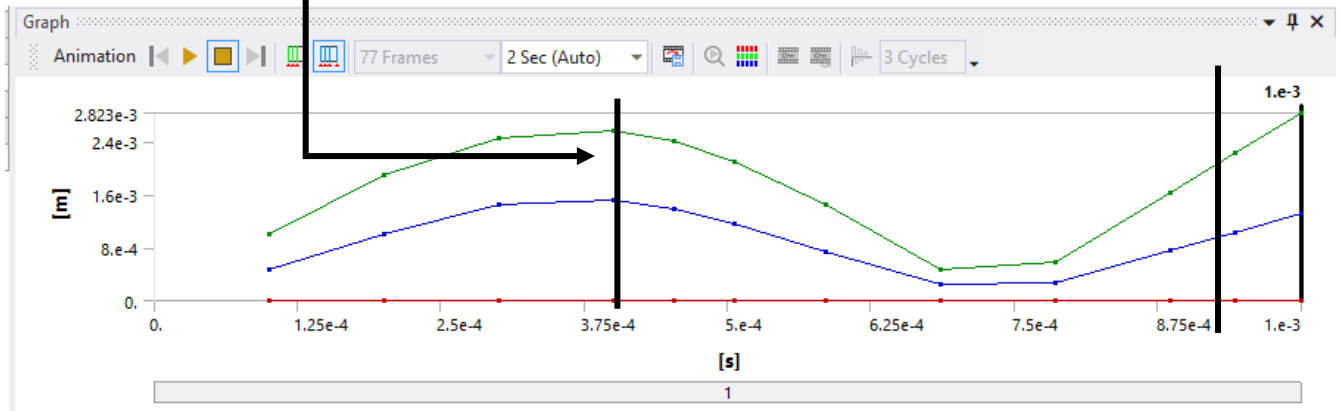


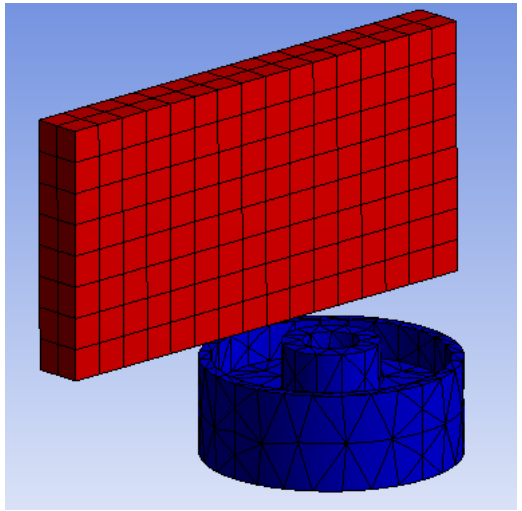
- Total Deformation Results
  - Use the Animation toolbar on the Graph Timeline to animate the results
  - It's useful to animate over Results Sets
  - The Timeline clearly shows the Striker has fully impacted and has begun its rebound



Full impact

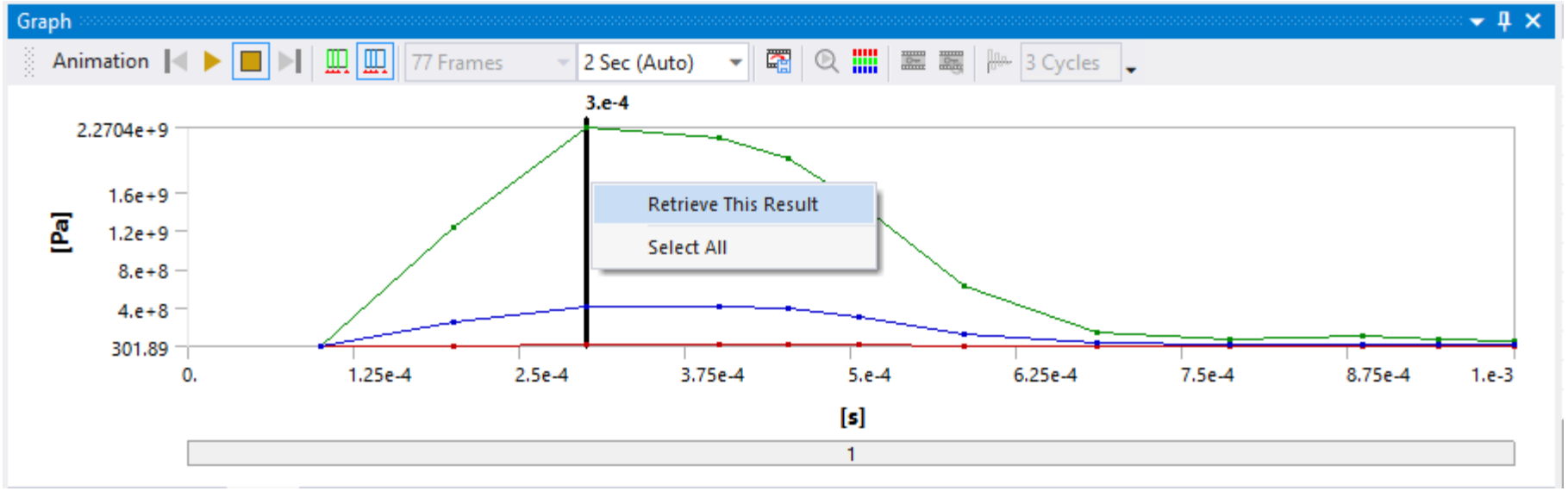
Rebound

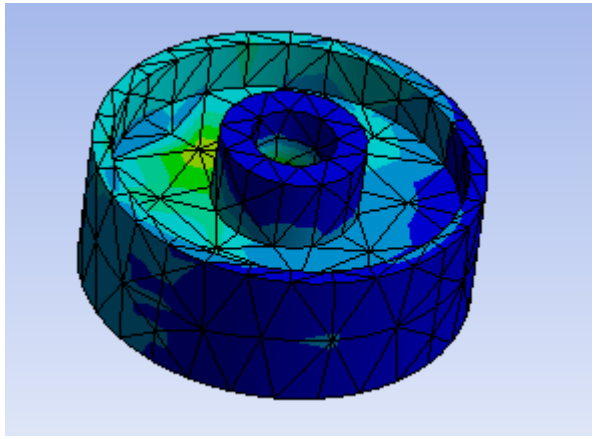




Workshop 09.1 - Results

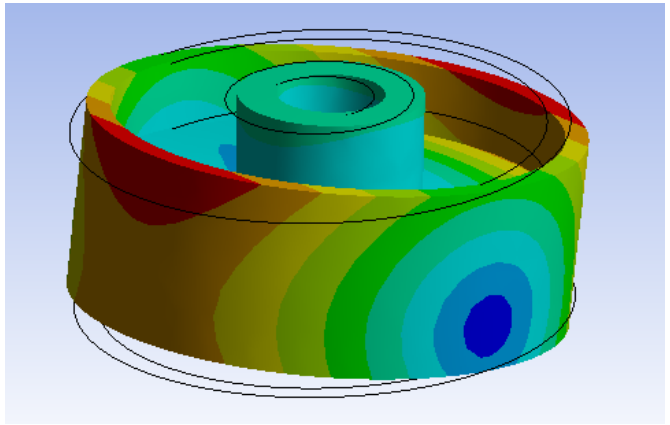
- Equivalent Stress Results
  - The Timeline shows a peak stress at 3e-4 seconds into the impact event.
  - Select that time point in the graph, then right mouse button, Retrieve this Result
  - The graph is not completely smooth, indicating there may be a higher stress result at a time shortly after 3e-4 seconds, however our chosen time step size did not permit a solution at that time interval.





Workshop 09.1 – Refine the Solution

- Refine the time step sizes used in this solution
  - The initial and minimum time step sizes can be arbitrarily decreased, or, a better method of estimating time step size is to conduct a Modal analysis.
  - This exercise is left to the student, with the following guidance:
    - Return to the Project Schematic and Duplicate the Transient Structural system
    - In the duplicated system, right mouse button on Cell B1 and Replace With … Modal
    - Open the Modal analysis system and suppress the Striker part
    - Delete all loads and supports except the fixed support on the Caster Wheel bore
    - Solve the modal analysis, requesting 6 modes
    - The first mode shape, approximately 2930 Hz, is indicative of the response we would expect from the Striker impacting the Wheel. Use this frequency to estimate the time step size for the transient.



Tabular Data

	Mode	Frequency [Hz]
1	1.	2930.7
2	2.	2933.1
3	3.	2953.2
4	4.	5020.9
5	5.	5032.9
6	6.	5064.5

Workshop 09.1 – Refine the Solution

- A good estimate of the time step size is:
  - Using 2930 Hz, the initial time step size calculates as 1.71e-5 s
  - We'll use 1.5e-5 s for this model

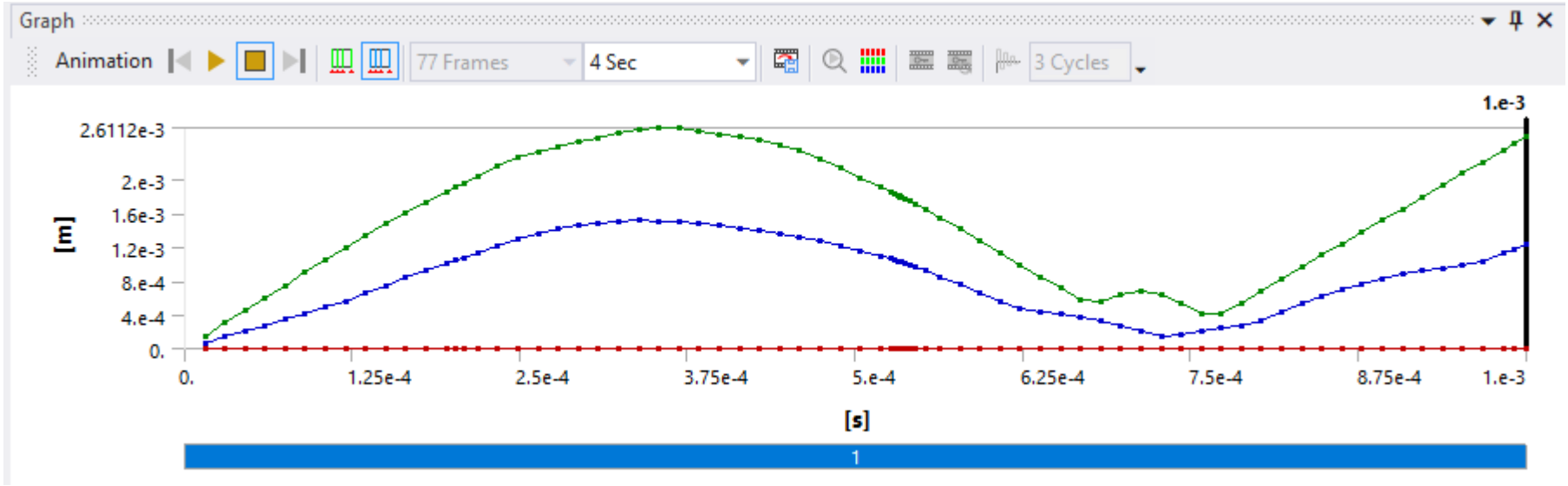
$$\Delta t_{initial} = \frac{1}{20\, f_{response}}$$

- Change the time step sizes for the Transient as follows and solve the transient solution again. Since the solution runs quickly, we're setting the maximum and initial time step sizes equal.

Details of "Analysis Settings"	
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1.e-003 s
Auto Time Stepping	On
Define By	Time
Initial Time Step	1.5e-005 s
Minimum Time Step	1.5e-007 s
Maximum Time Step	1.5e-005 s
Time Integration	On
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Large Deflection	On

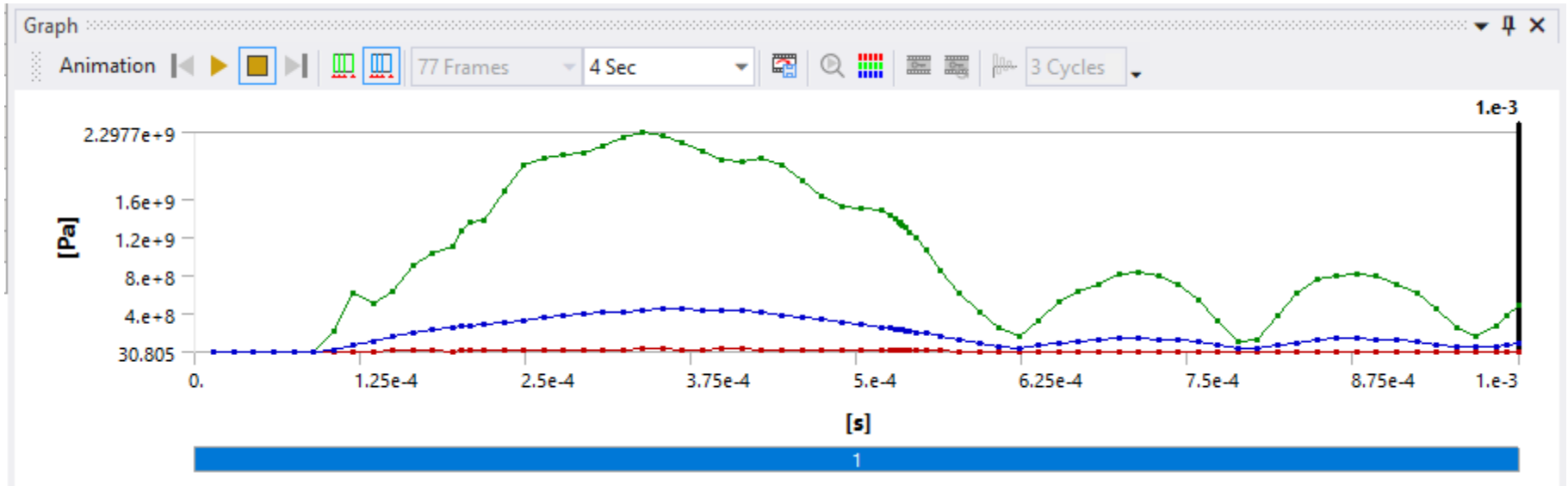
Workshop 09.1 – Refined Results

- Total deformation results still show a smooth variation over time.



Workshop 09.1 – Refined Results

- Equivalent Stress results are now much smoother as well, giving more confidence that we did not miss any stress peaks in the time history.
- If time permits, make note of your results, insert appropriate mesh sizing controls, enter a smaller “Element Size” value, solve again, and compare results.



End of presentation