Ansys Mechanical Linear and Nonlinear Dynamics

WS 02.1: SDOF Oscillators

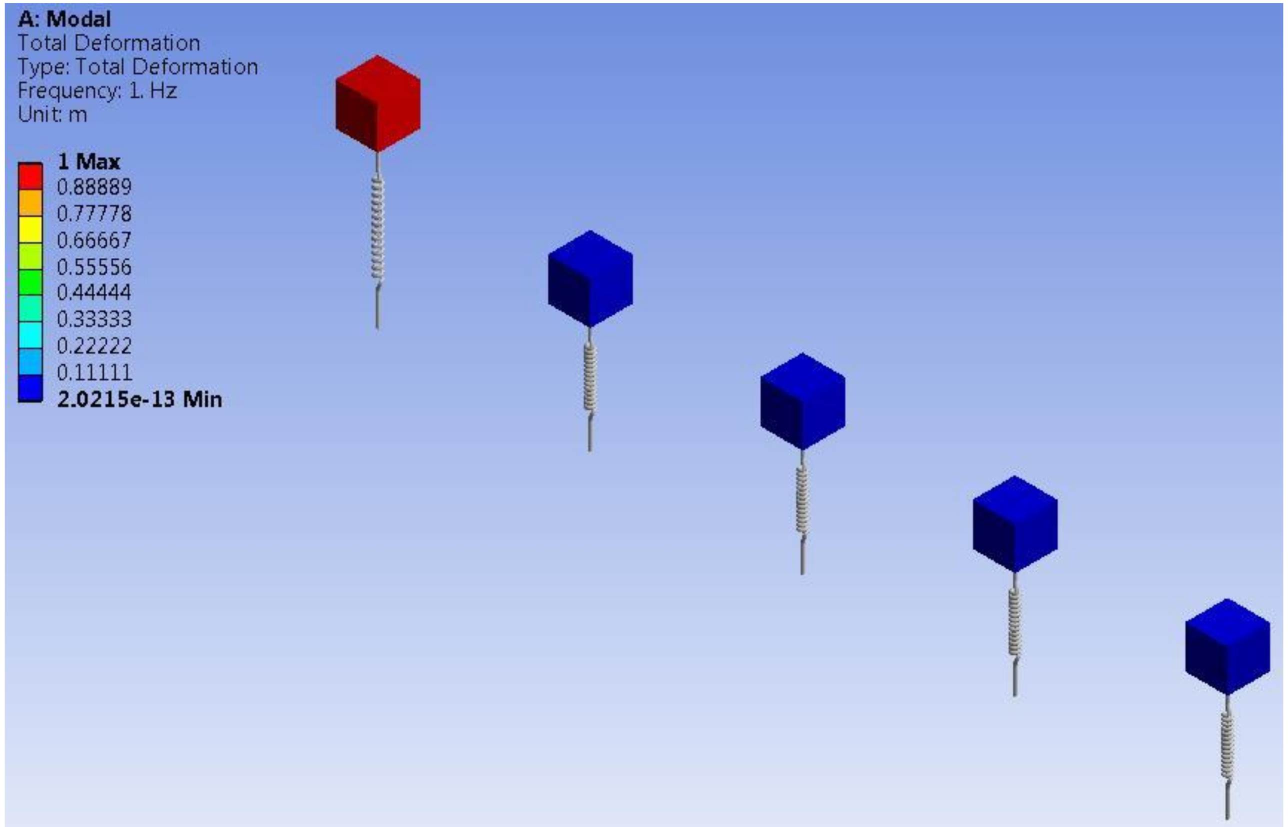
Release 2022 R2

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 02.1 - Goals

- The objective of this workshop is to understand how to apply damping in an analysis and to observe the effect of damping on a series of single-degree-of-freedom oscillators.



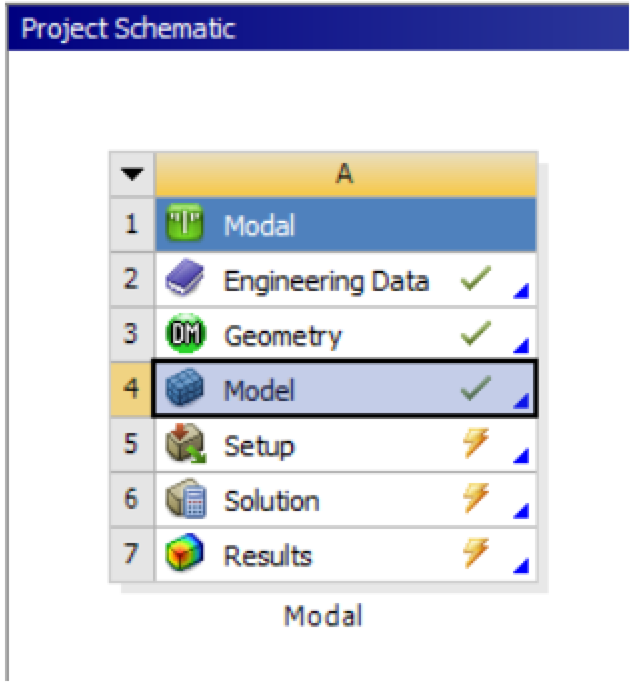
Workshop 02.1 - Description

- We assume a discrete-component model consisting of 5 mass-spring systems, each having mass of 1 kg. The value of each spring's stiffness is chosen to result in the following natural frequencies:

- K_1 = 39.48 N/m → $f_1 = (1/2\pi)\sqrt{K_1/m_1} = 1.0$ Hz
- K_2 = 88.83 N/m → $f_2 = (1/2\pi)\sqrt{K_2/m_2} = 1.5$ Hz
- K_3 = 157.92 N/m → $f_3 = (1/2\pi)\sqrt{K_3/m_3} = 2.0$ Hz
- K_4 = 355.3 N/m → $f_4 = (1/2\pi)\sqrt{K_4/m_4} = 3.0$ Hz
- K_5 = 631.65 N/m → $f_5 = (1/2\pi)\sqrt{K_5/m_5} = 4.0$ Hz

Workshop 02.1 - Project Schematic

- Begin a new Workbench session and open the provided project archive: “**WS02.1-SDOF_Oscillators.wbpz**”

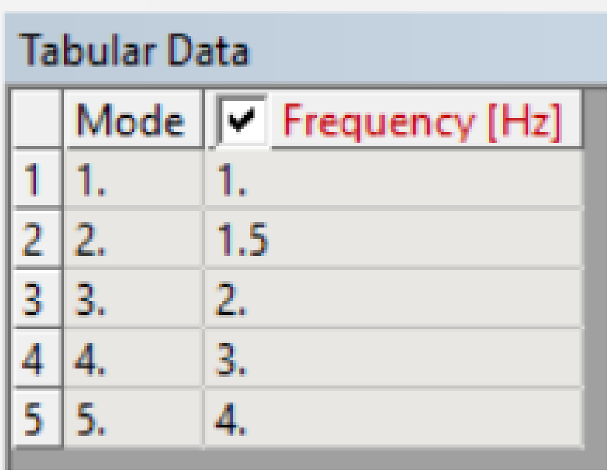


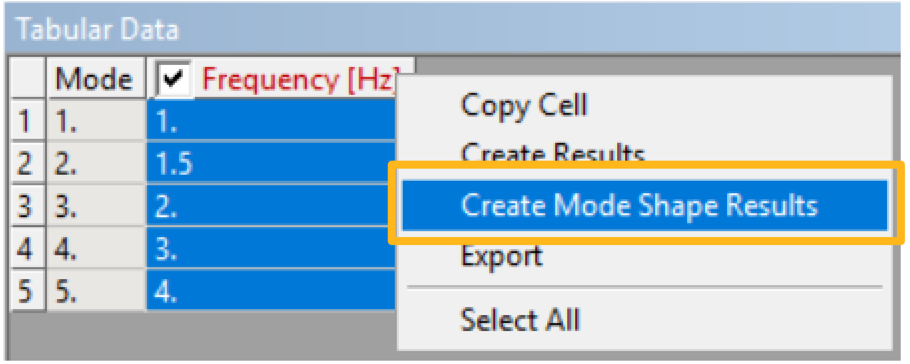
Workshop 02.1 – Modal Analysis

- Open Mechanical from the Modal Analysis Model cell.
  - Within Mechanical, set the Units to “Metric (m, kg, N, s, V, A)”.
- Frictionless supports have been defined on each mass to restrict deformation only to the Y translation DOF.
- Under Modal > Analysis Settings ensure that:
  - “Max Modes to Find” is set to “5”, and
  - “Solver Controls> Damped” is set to “No”
  - Damping will be defined in a subsequent harmonic response analysis where we can see its effect on the response of the system.
- Solve
  - The modal analysis simply serves to allow us to review the natural frequency and mode shape for each spring-mass system.

Workshop 02.1 – Modal Postprocessing

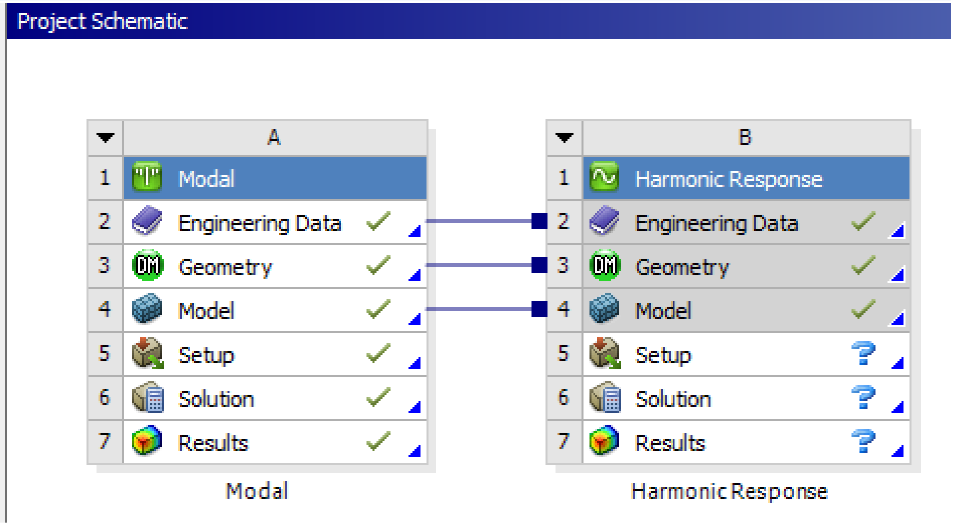
- Highlight the Solution branch and confirm that the first 5 natural frequencies are as expected.
- Examine the deformation of each mode by creating Mode Shape Results.
  - Select the Frequency column of the Tabular Data
  - Right-mouse-button, Create Mode Shape Results
- Evaluate these results and review each one.





Workshop 02.1 – Harmonic Analysis

- In the project Schematic, drag a “Harmonic Response” system and drop it on the “Model” cell of the Modal system.
  - We are not transferring Modal results to the Harmonic Response.
  - Unlike WS 01.1, the Harmonic analysis will not use the results from the modal analysis in order to predict the response. Instead, it will be computed as a “Full Solution” (covered later in Harmonic Analysis Module).



Workshop 02.1 – Harmonic Preprocessing

- Under Analysis Settings for the Harmonic Response analysis, set the following:
  - Range Minimum: 0 Hz
  - Range Maximum: 4.5 Hz
  - Solution Intervals: 100
  - User Defined Frequencies: On
    - Define User Defined Frequency Steps of 1, 1.5, 2, 3, and 4 Hz in Tabular Data
  - Solution Method: Full
  - Constant Structural Damping Coefficient : .04
- The above settings will conduct 100 equally-spaced solutions between 0 Hz and 4.5 Hz (i.e. at every 0.045 Hz); User Defined Frequencies will also force solutions at our spring-mass natural frequencies, thus assuring we're capturing maximum responses.

Details of "Analysis Settings"

Step Controls	
Multiple RPMs	No
Options	
Frequency Spacing	Linear
Range Minimum	0. Hz
Range Maximum	4.5 Hz
Solution Intervals	100
User Defined Frequencies	On
Solution Method	Full
Variational Technology	Program Controlled
Rotordynamics Controls	
Output Controls	
Damping Controls	
Constant Structural Damping Coefficient	4.e-002
Stiffness Coefficient Define By	Direct Input
Stiffness Coefficient	0.
Mass Coefficient	0.

Tabular Data

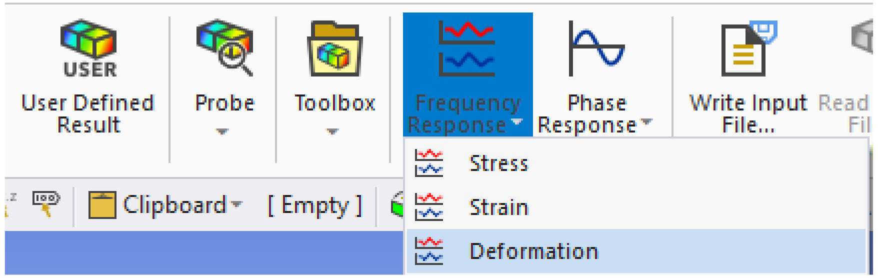
	User Defined Frequency Steps [Hz]
1	1.
2	1.5
3	2.
4	3.
5	4.
*	

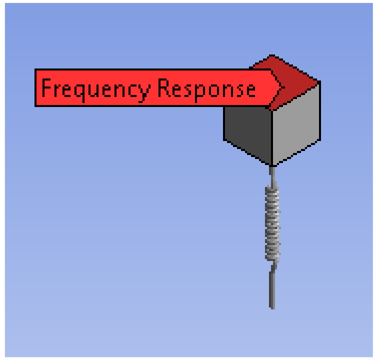
Workshop 02.1 – Harmonic Preprocessing

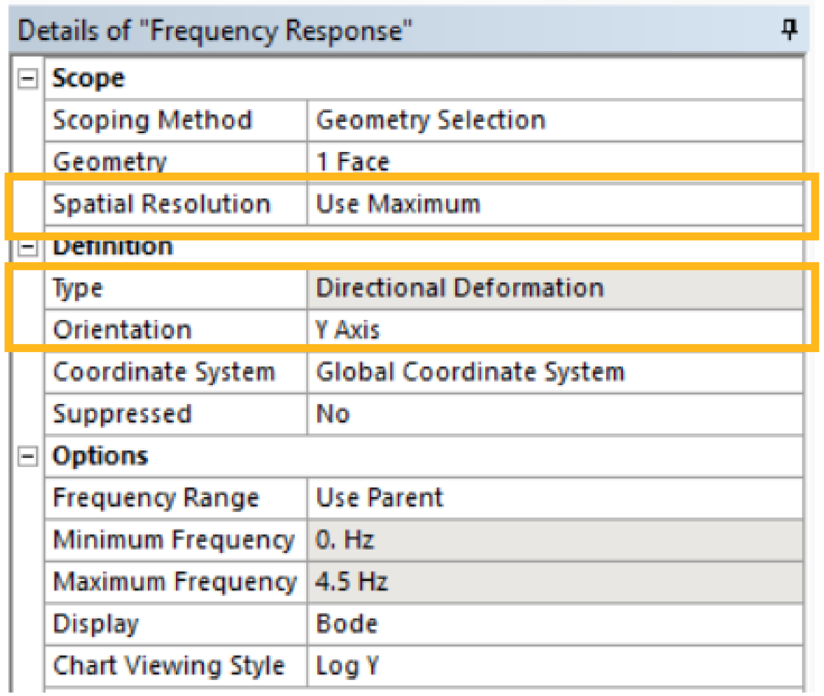
- Drag the Frictionless Support from the Modal Analysis and drop it on the Harmonic Analysis branch.
- Insert a 0.1 G (0.981 m/s^2) acceleration load in the Y direction.
- Solve.

Workshop 02.1 – Harmonic Postprocessing

- Insert a Deformation Frequency Response, and scope it to the top face of the first mass.
  - Spatial Resolution: Use Maximum
  - Orientation: Y Axis
- Repeat the above procedure for the other four masses.
- Evaluate Results





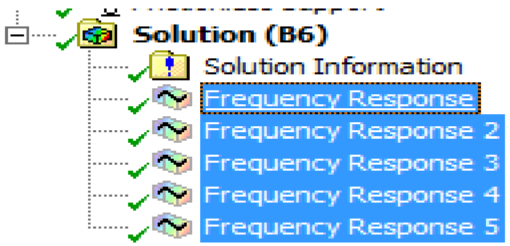


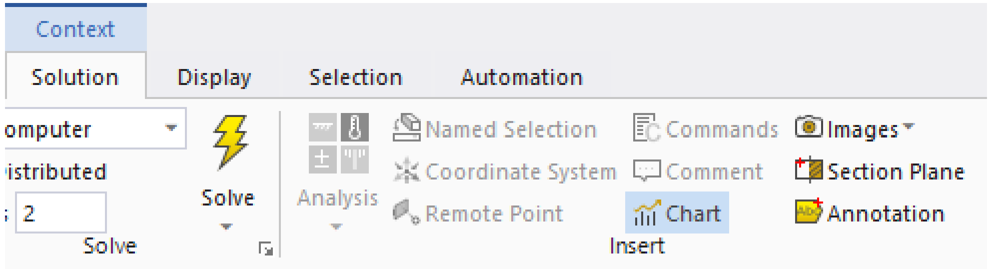
Details of "Frequency Response"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Spatial Resolution	Use Maximum
Definition	
Type	Directional Deformation
Orientation	Y Axis
Coordinate System	Global Coordinate System
Suppressed	No
Options	
Frequency Range	Use Parent
Minimum Frequency	0. Hz
Maximum Frequency	4.5 Hz
Display	Bode
Chart Viewing Style	Log Y

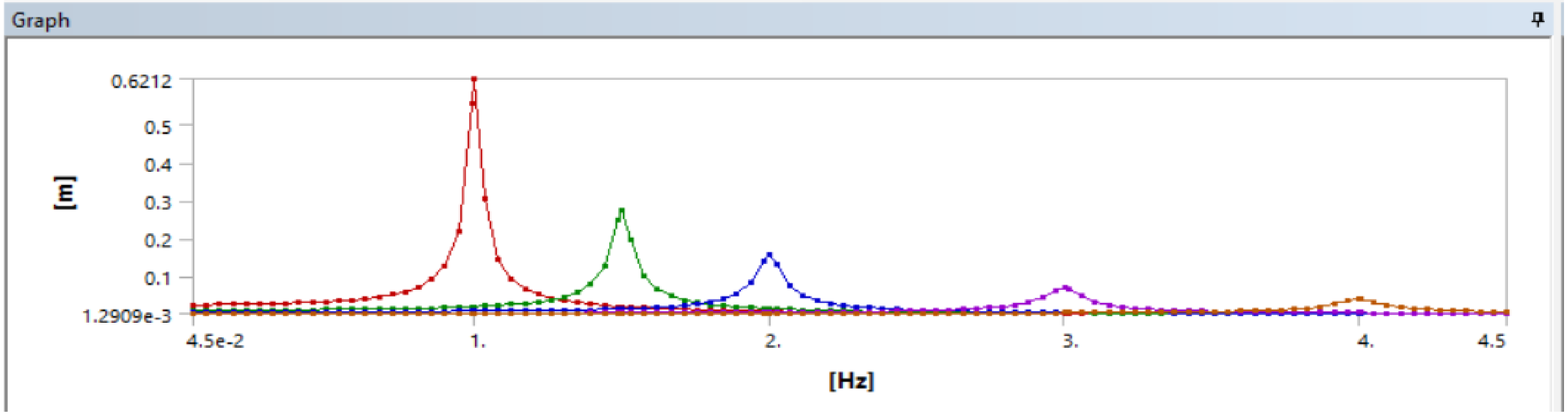
Workshop 02.1 – Harmonic Postprocessing

- Highlight the 5 frequency responses created, then click on “Chart”
  - You can omit the Phase Angle Output Quantities in the Details of the Chart object.





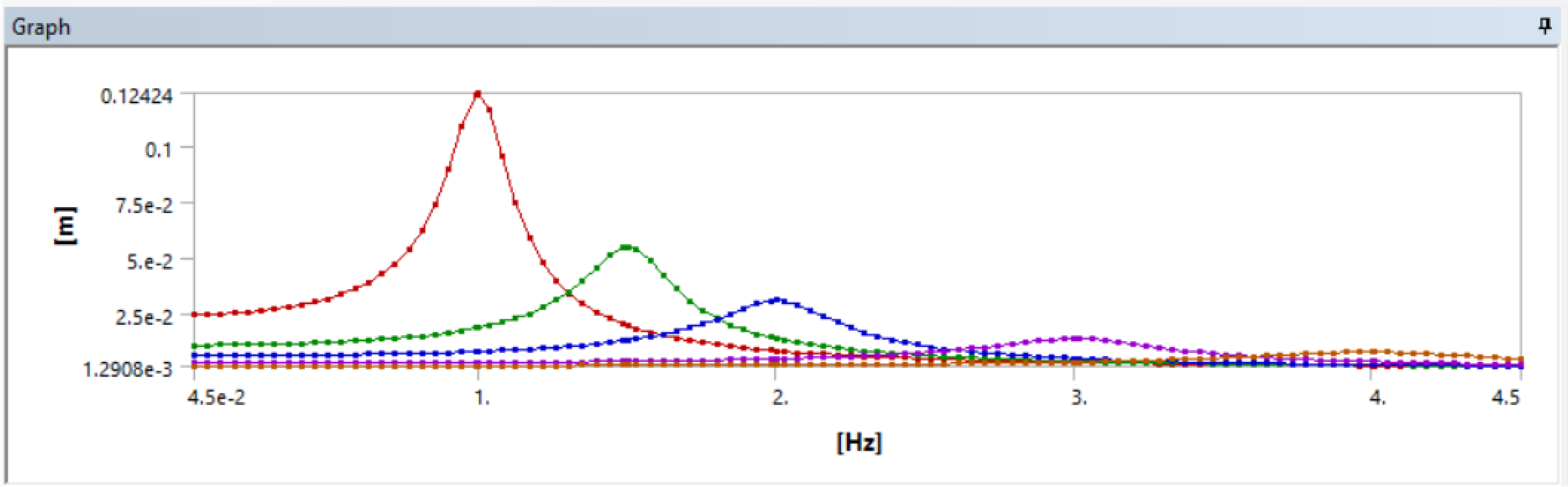
Note the amplitude for each mass at its natural frequency.



Workshop 02.1 – Harmonic Postprocessing

- Repeat the harmonic analysis, but with a higher damping.
  - Change the Constant Structural Damping Coefficient to 0.2
- Solve

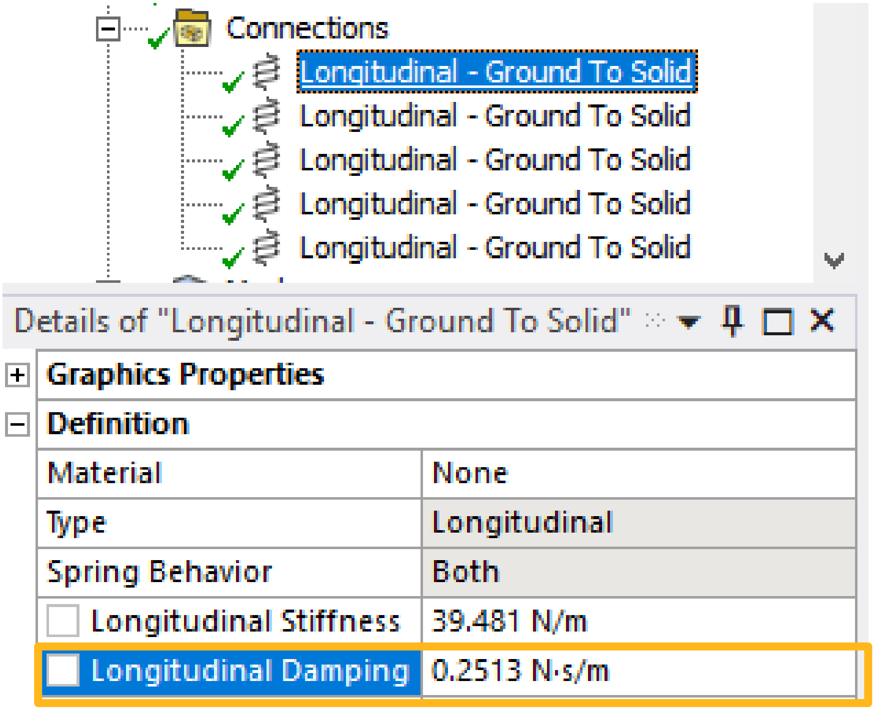
Workshop 02.1 – Harmonic Postprocessing



Note the amplitudes that are obtained for each mass and compare them to the previous damped case.

Workshop 02.1 – Go Further!

- Given the relationship between the damping ratio and the constant structural damping coefficient ($2\xi = g$) and knowing that element viscous damping $c = \xi C_c$, calculate the required damping in each spring connection to yield the same response as the case in which $g = 0.04$.
- For example, the first spring connection:
  - $k = 39.481$ n/m and $m = 1$ kg
  - $\xi = g/2 = 0.02$
  - $C_c = 2\sqrt{(km)}$
  - Therefore, $c = 2\xi\sqrt{(km)} = 2(0.02)\sqrt{(39.481)} = 0.2513$ N-s/m
- Calculate c as above for remaining springs
- Re-run harmonic with $g = 0$, do results match Slide 11?



End of presentation