Nonlinear Vibrations of Aerospace Structures

Tutorial 01:
Introduction to NI2D

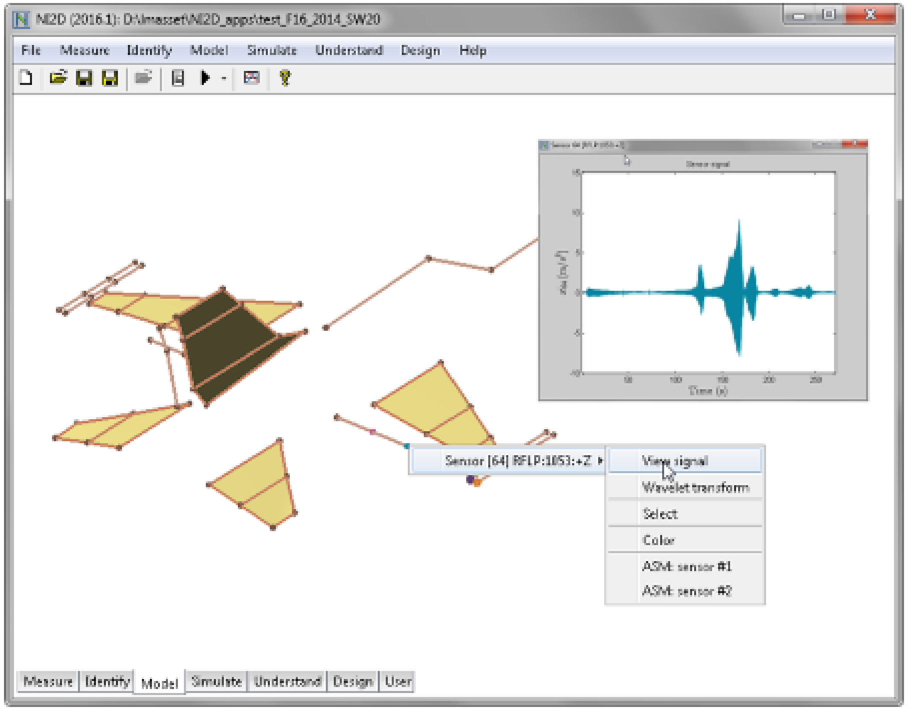
Nonlinear Identification to Design
Software

Tutorials and project in the NI2D software

Free access to the NI2D software commercialized by the NOLISYS company.

Stand alone .exe.

Nonlinear Identification to Design
Software



NI2D philosophy

A prototype of the structure is available:

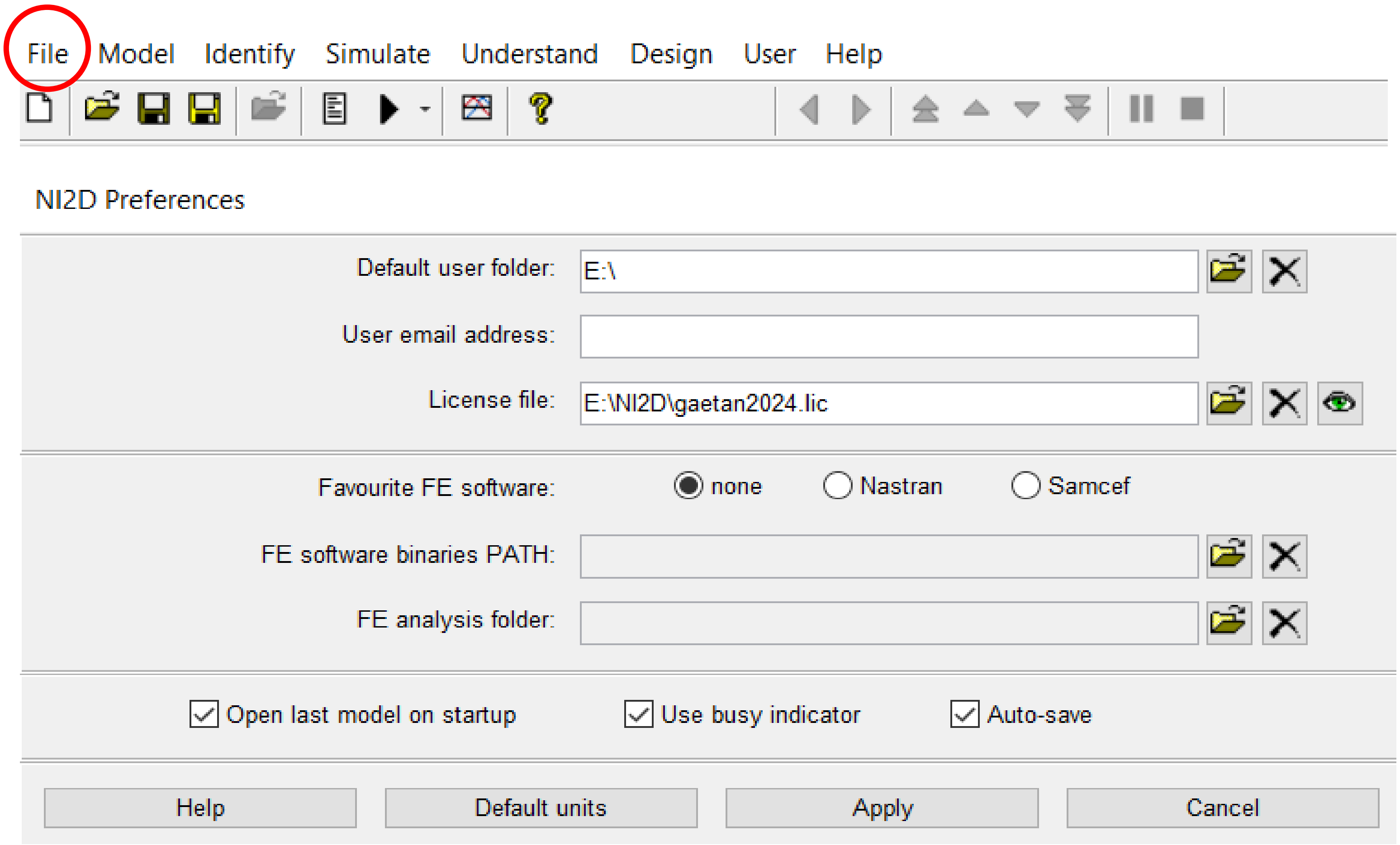
→ Test it, identify the nonlinearities and upgrade the linear FEM.

A priori knowledge about the nonlinearities is available:

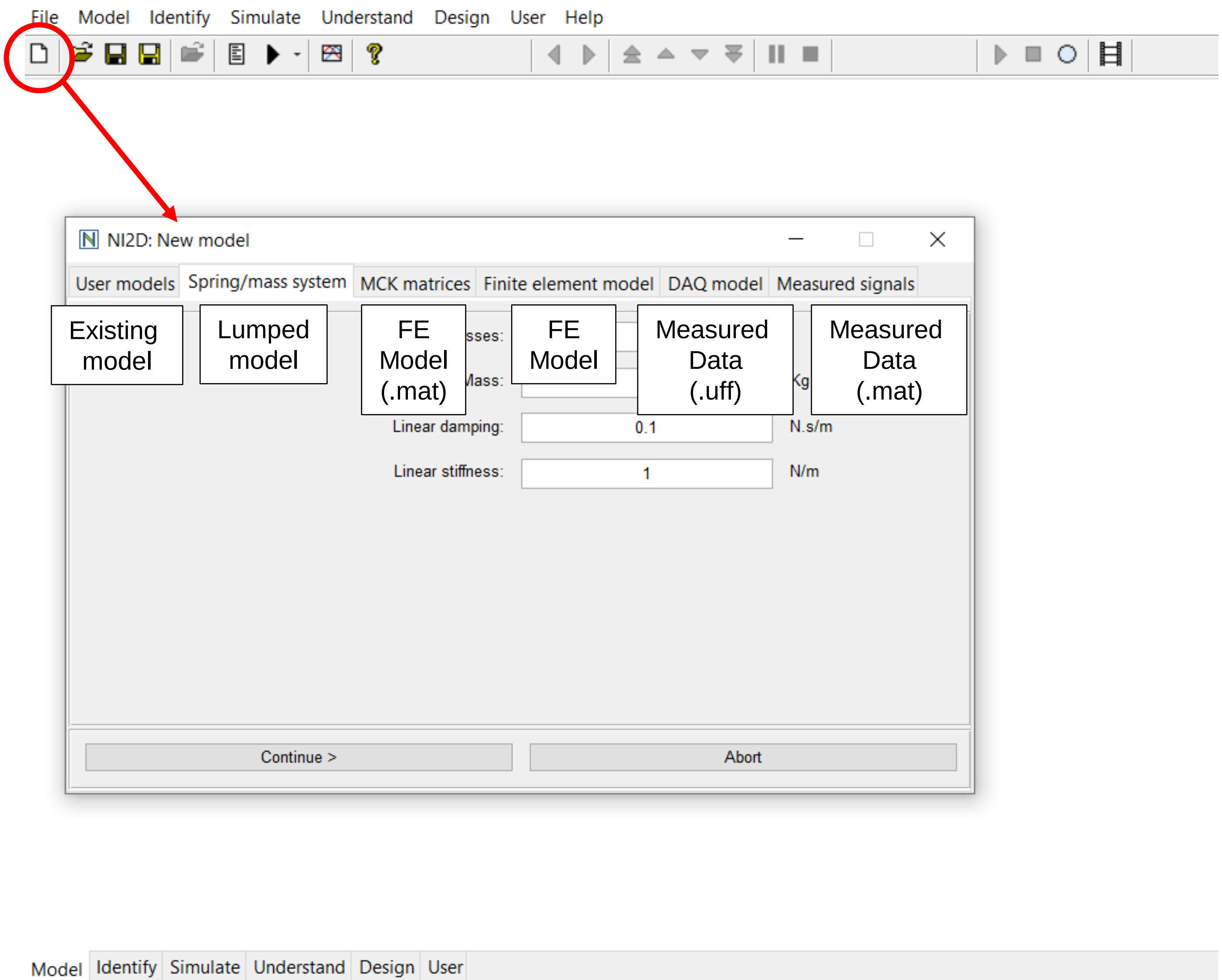
→ Load the linear FEM into NI2D and implement the nonlinearities using NI2D elements library.

Get started with NI2D

Launch NI2D and activate your license under *Preferences.*



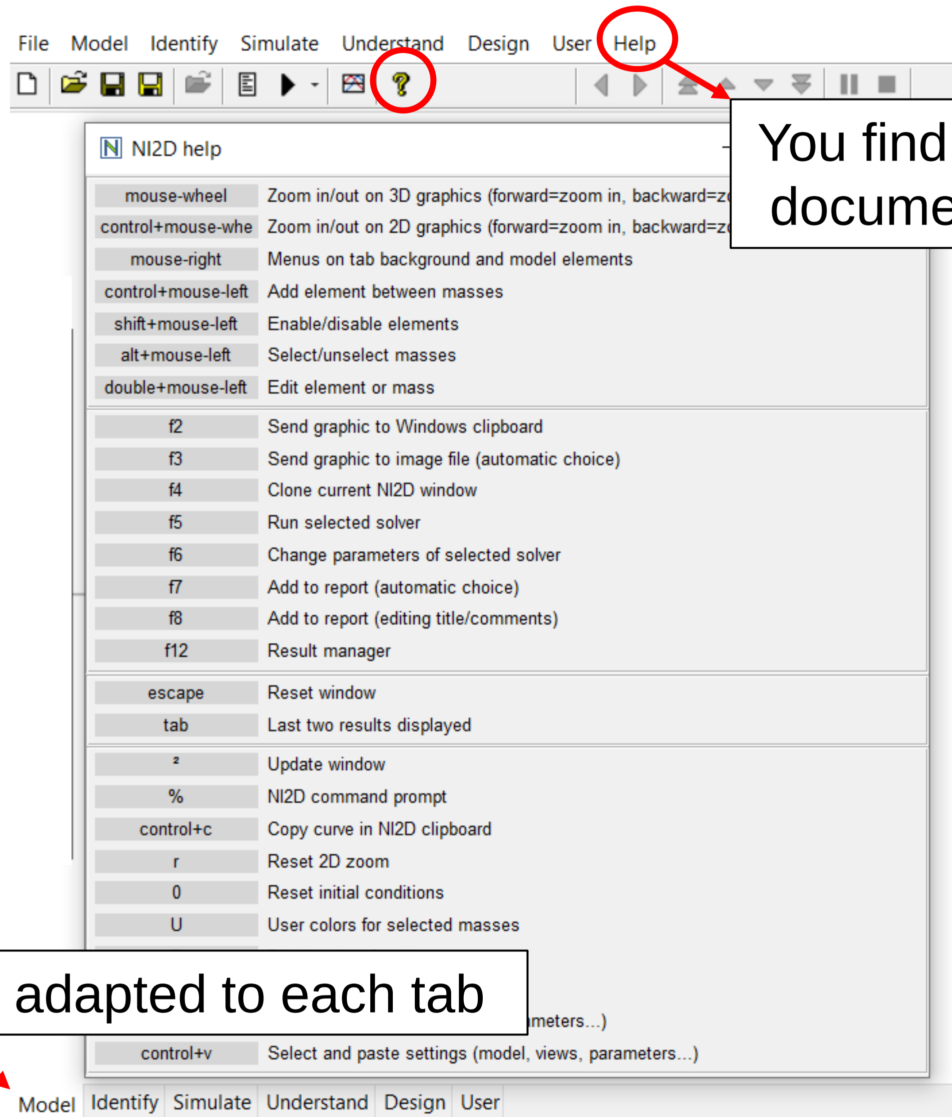
Create a new model



Open an existing model

Choose here

Need Help?



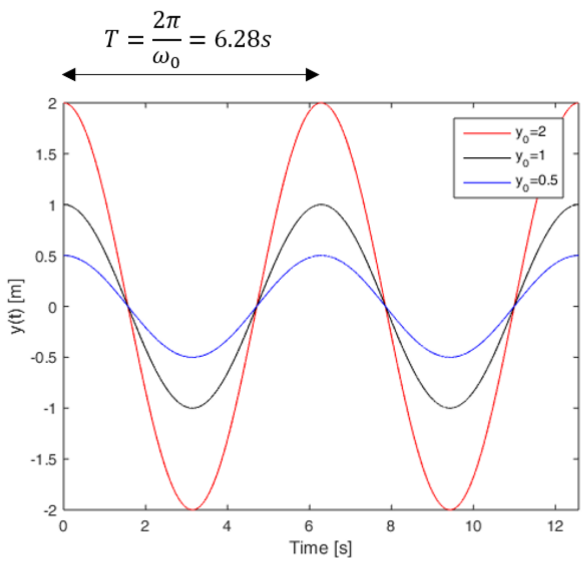
You find the software documentation here

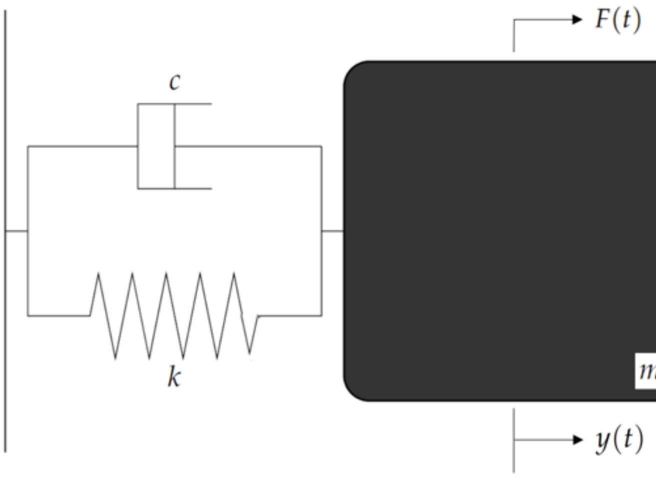
The help menu is adapted to each tab

Launch Your First Numerical Simulation

Let's reproduce the result of the previous lecture

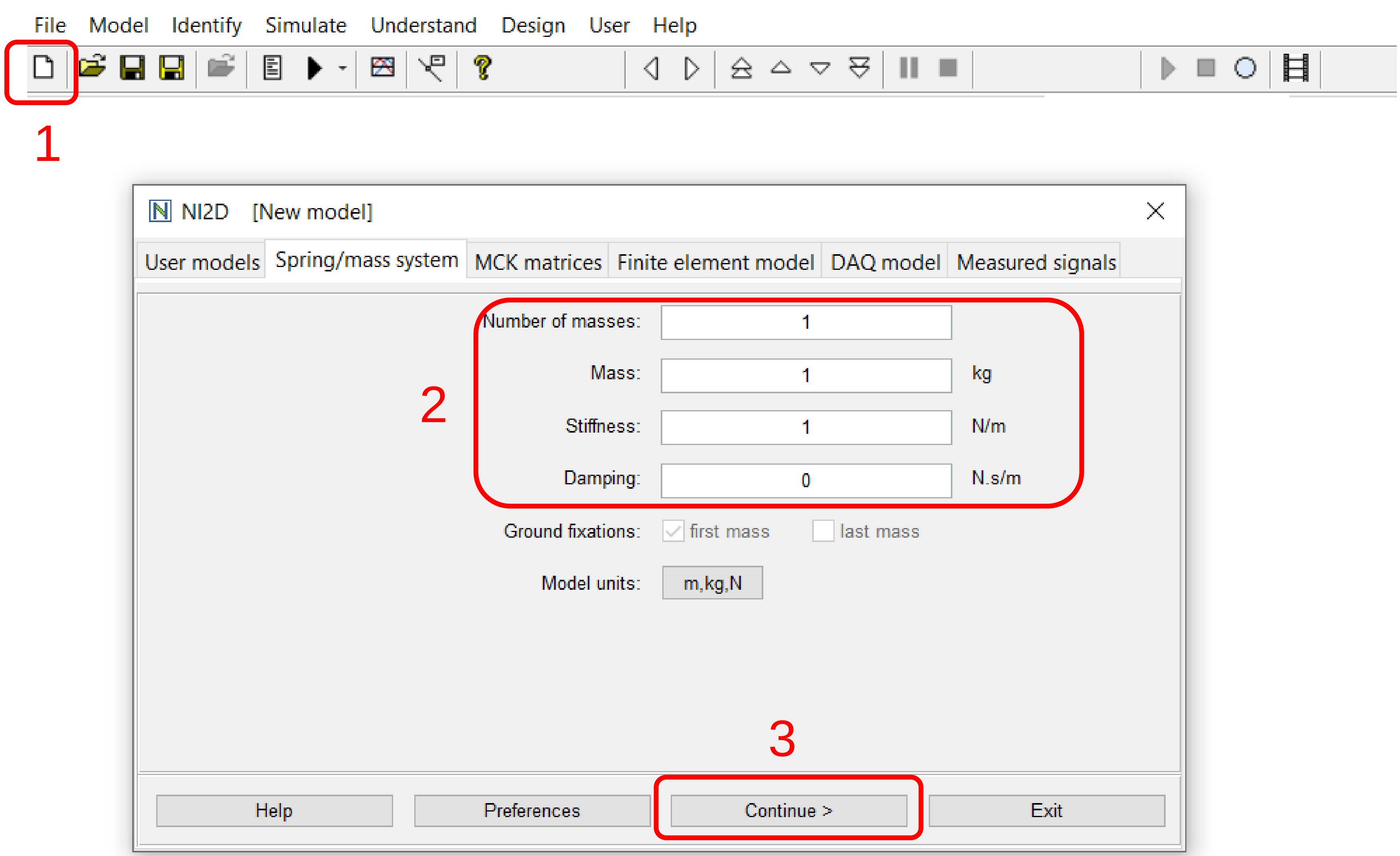
Response to different initial displacements ($\omega_0 = 1$)



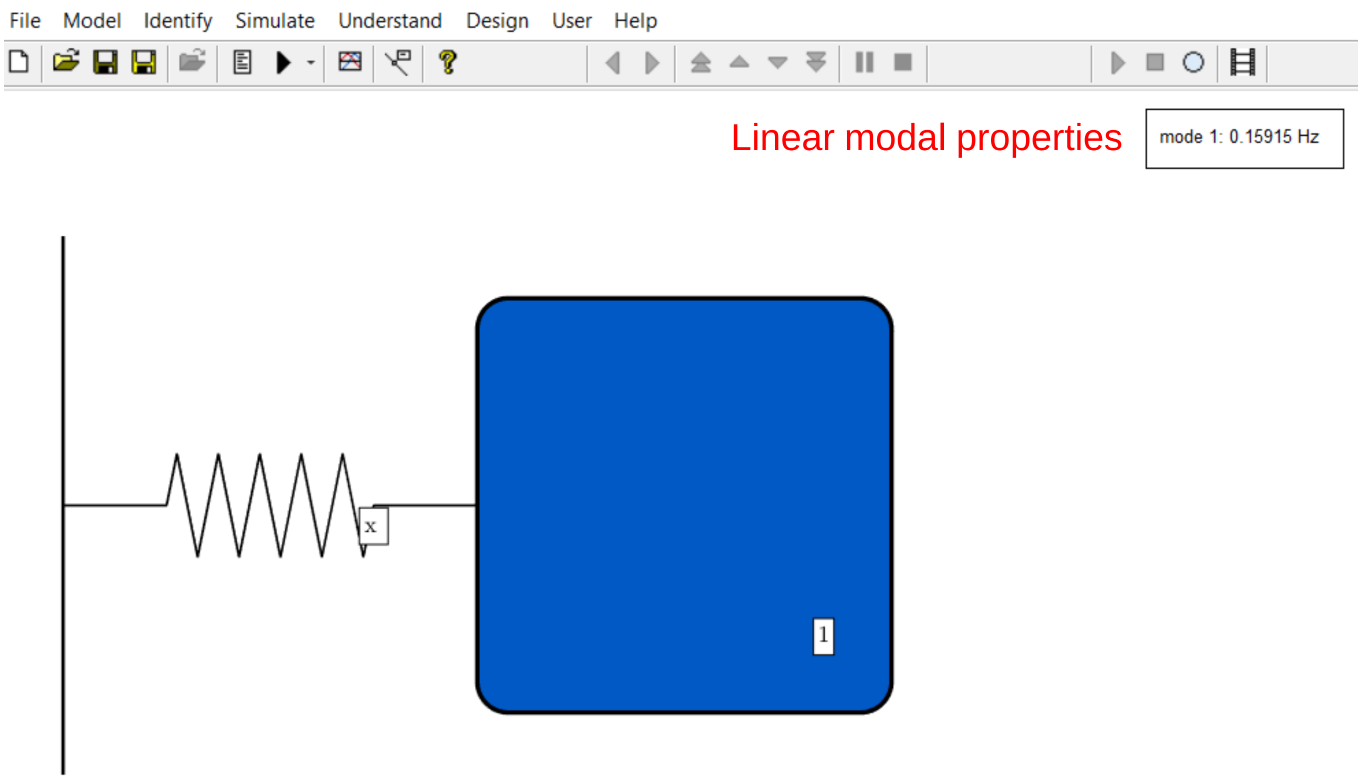


m=k=1, c=F(t)=0

Create a new model: 1 DOF linear oscillator

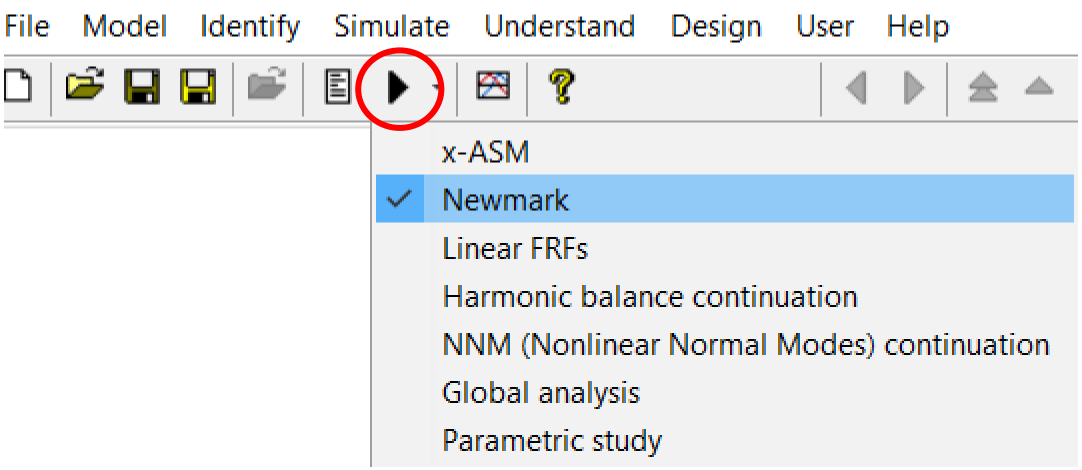


You can change the coefficients anytime …



Double click on the element to change the coefficients

Calculate the time response with Newmark



Crucial to choose the right sampling frequency

Algorithm	γ	β	**Stability** limit $\omega\, h$	**Accuracy**: Amplitude error $\rho - 1$	**Accuracy**: Periodicity error $\frac{\Delta T}{T}$
Purely explicit	0	0	0	$\frac{\omega^2 h^2}{4}$	$-$
Central difference	$\frac{1}{2}$	0	2	0	$-\frac{\omega^2 h^2}{24}$
Fox & Goodwin	$\frac{1}{2}$	$\frac{1}{12}$	2.45	0	$O(h^3)$
Linear acceleration	$\frac{1}{2}$	$\frac{1}{6}$	3.46	0	$\frac{\omega^2 h^2}{24}$
Average constant acceleration	$\frac{1}{2}$	$\frac{1}{4}$	∞	0	$\frac{\omega^2 h^2}{12}$
Average constant acceleration (modified)	$\frac{1}{2} + \alpha$	$\frac{(1+\alpha)^2}{4}$	∞	$\alpha - \frac{\omega^2 h^2}{2}$	$\frac{\omega^2 h^2}{12}$

How many points per period ?

Average constant acceleration	$\frac{1}{2}$	$\frac{1}{4}$	∞	0	$\frac{\omega^2 h^2}{12}$

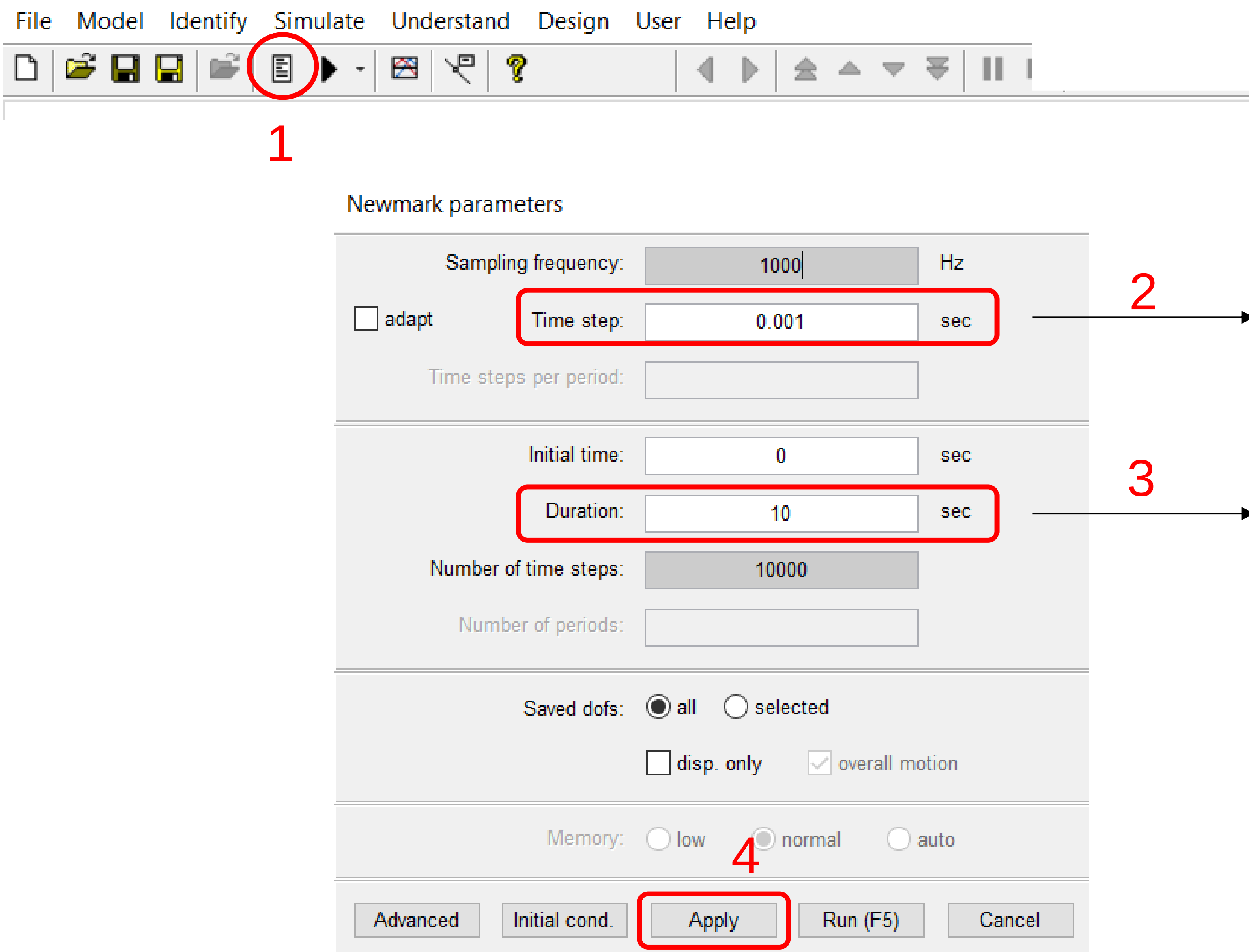
Error for 20 points per period:

$$\frac{\omega^2 h^2}{12} = \frac{\left(\frac{2\pi}{T}\right)^2 \left(\frac{T}{20}\right)^2}{12} = \frac{39.4}{400.12} = 0.0082 = 0.82\%$$

Error for 100 points per period:

$$\frac{\omega^2 h^2}{12} = \frac{\left(\frac{2\pi}{T}\right)^2 \left(\frac{T}{100}\right)^2}{12} \approx \frac{39.4}{10000.12} = 0.0003 = 0.03\%$$

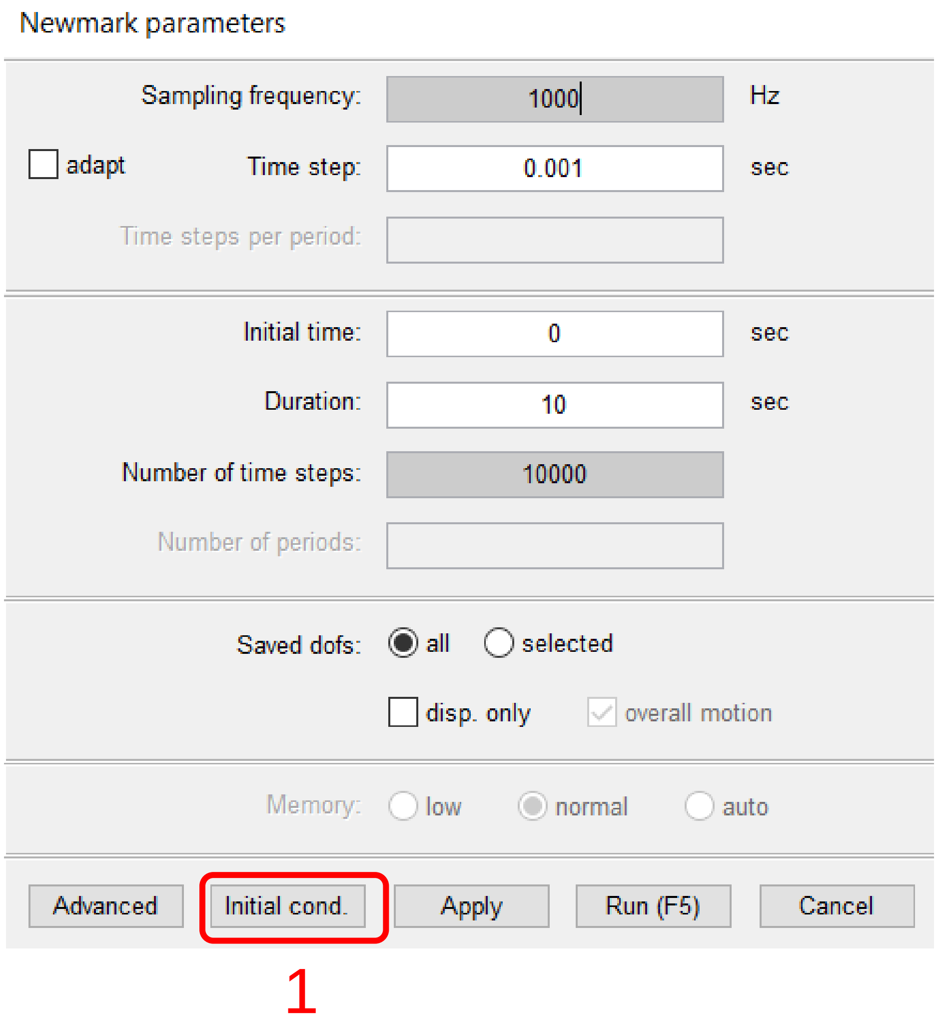
Select an appropriate time step and the final time

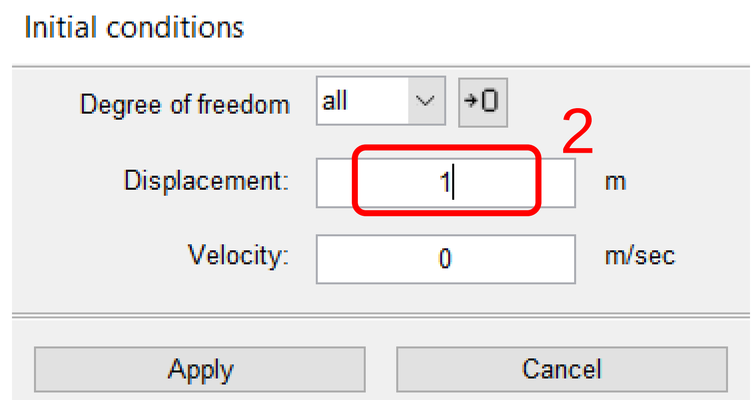


0.01 sec (628 points per period)

20 sec

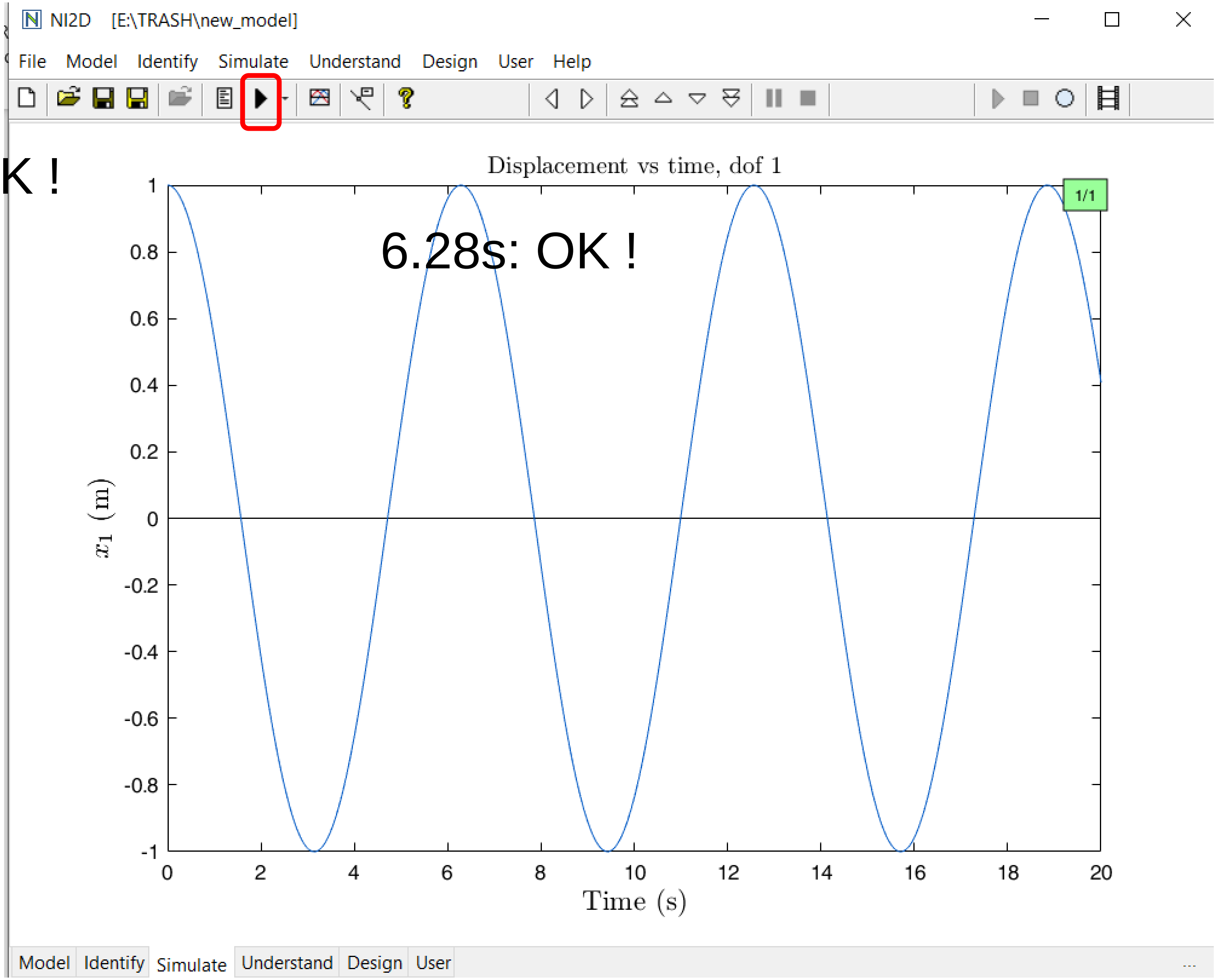
Specify initial conditions



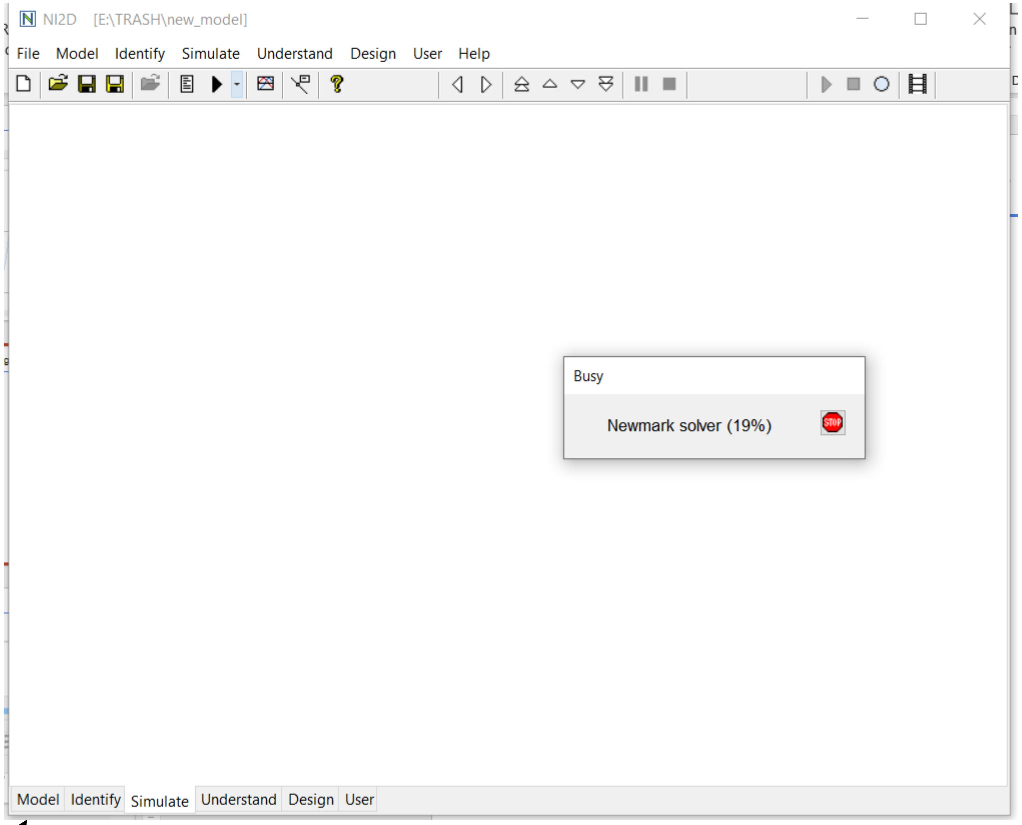


Run the simulation

1m: OK !



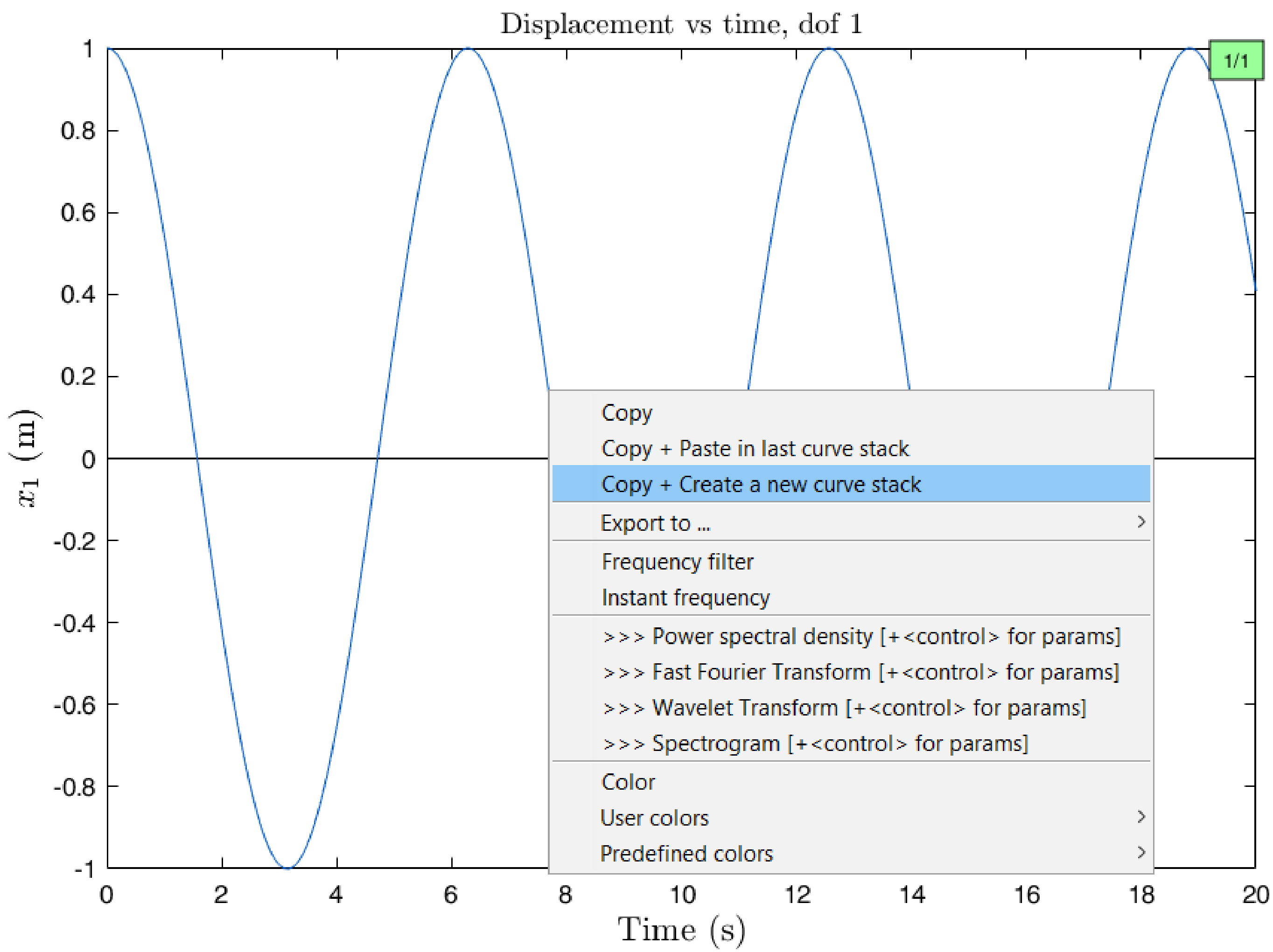
Progress window: useful for long simulations but slows down simple simulations



Type ‘W’ in the model tab to remove it

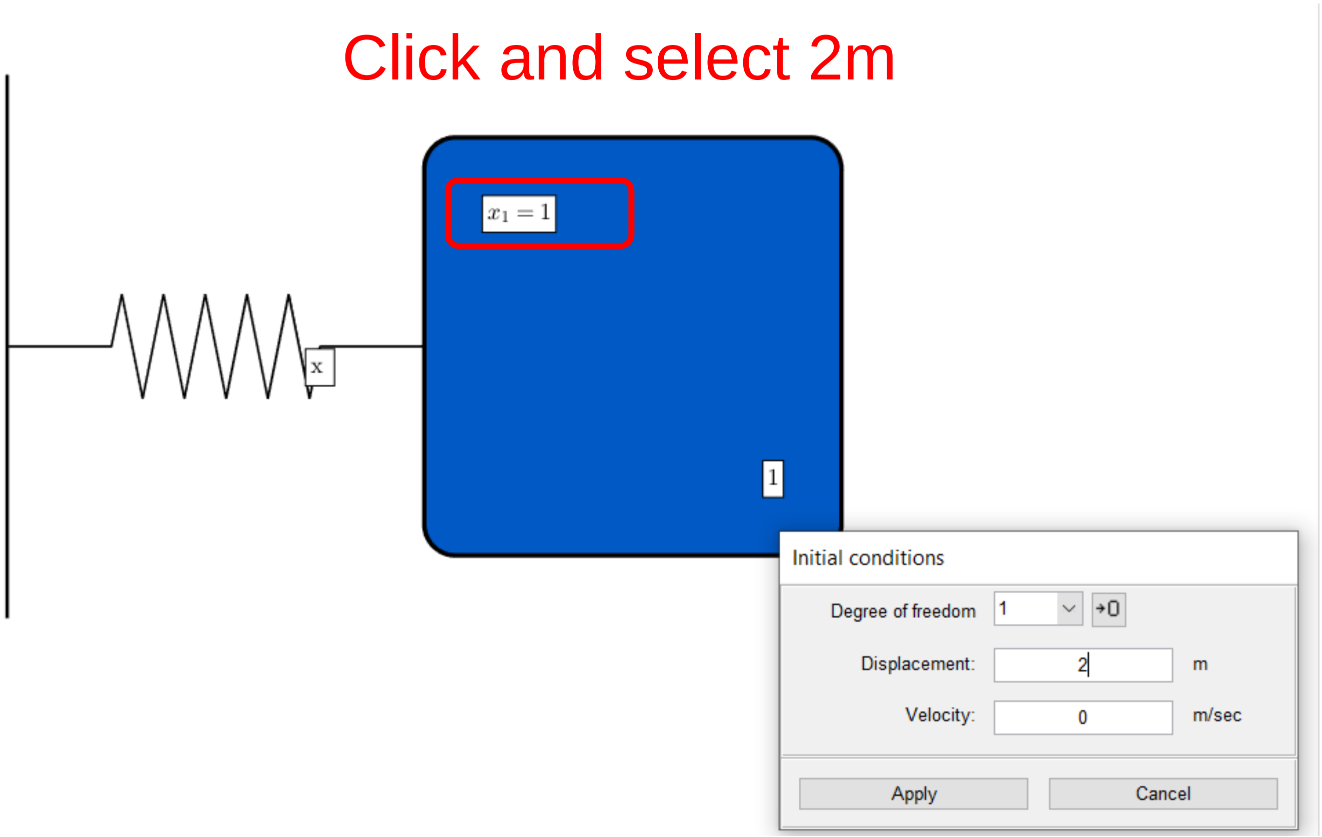
Send the result to the user tab

Right click on the curve

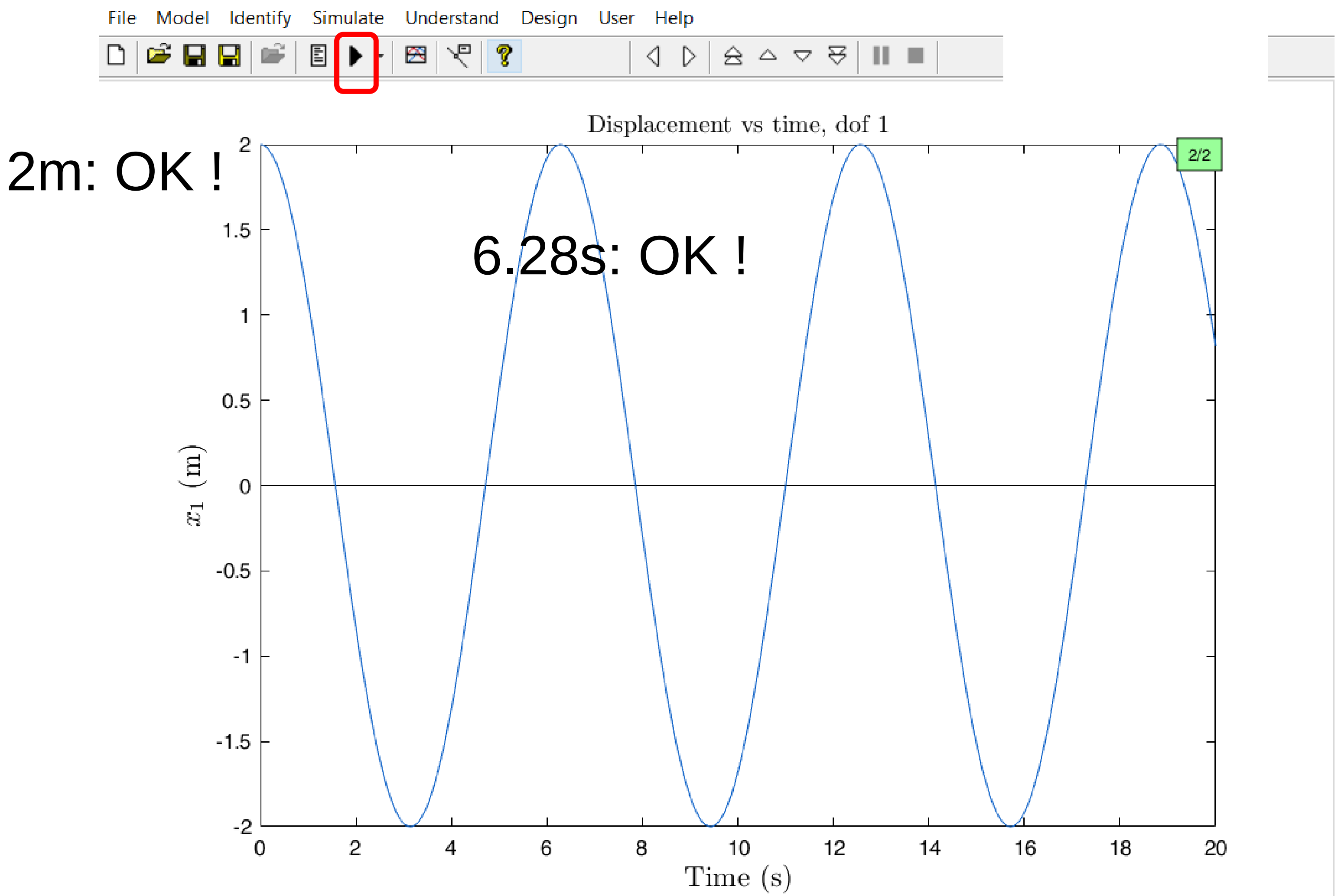


Specify different initial conditions

Click and select 2m

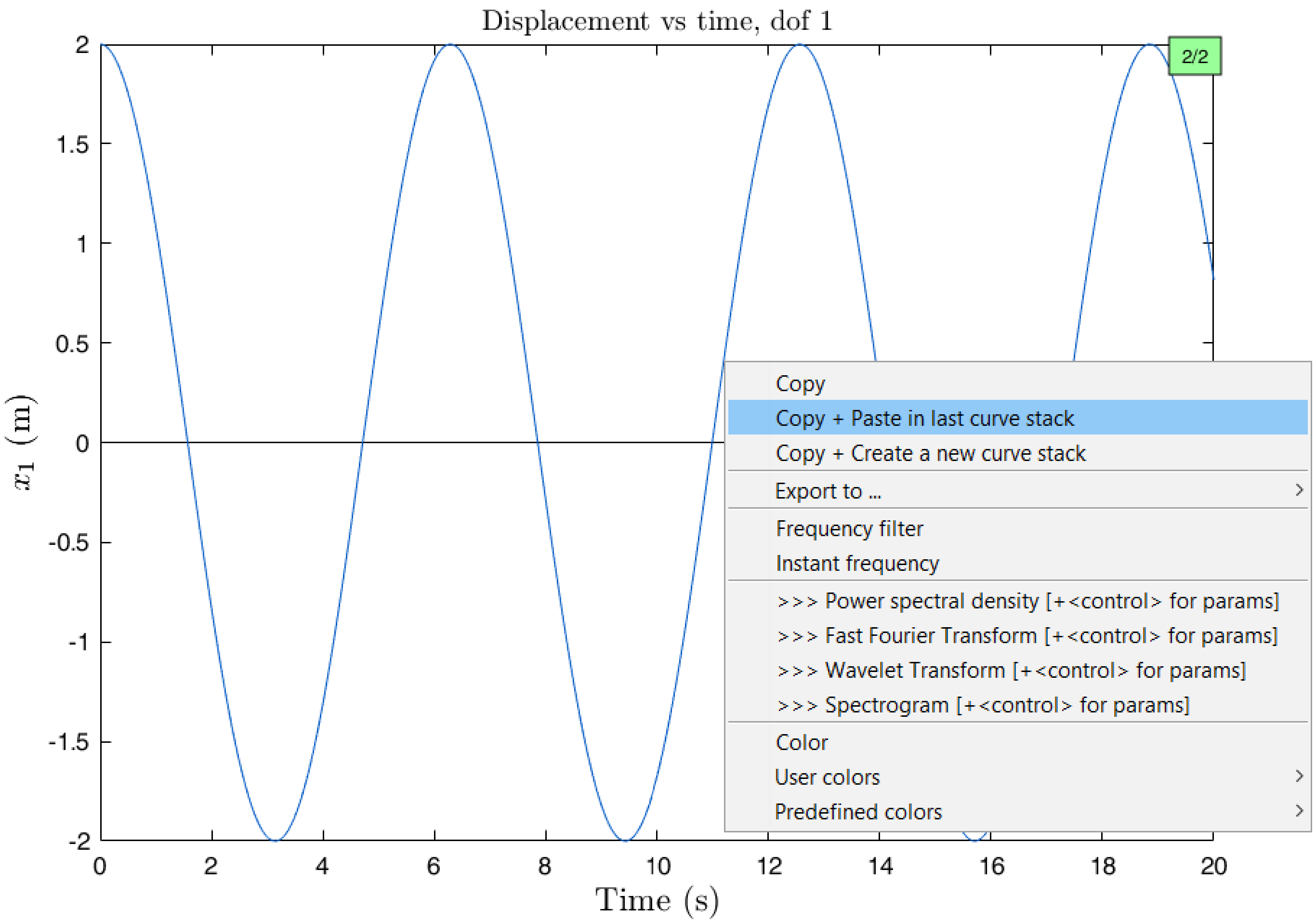


Run the simulation

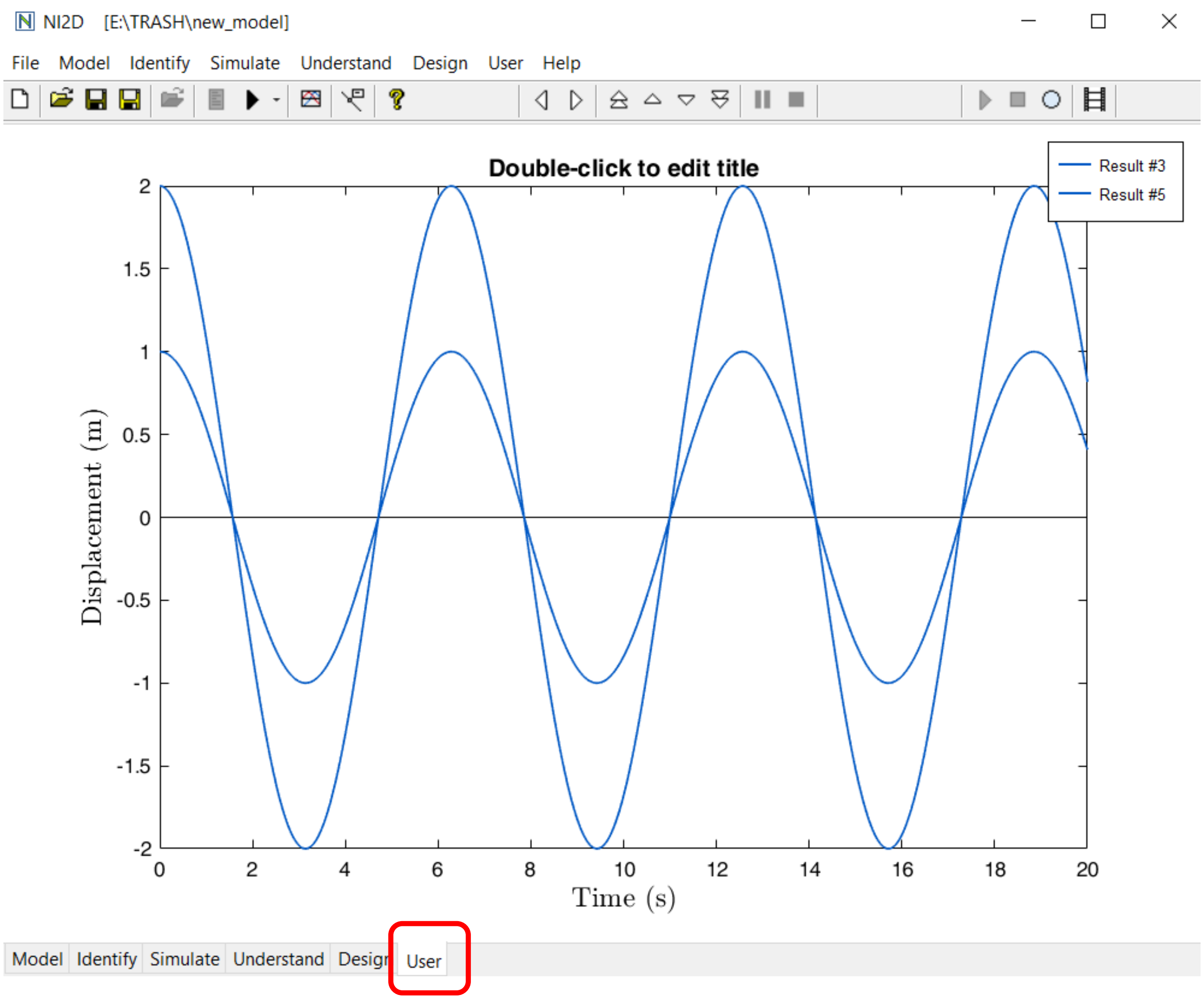


Send the result to the user tab

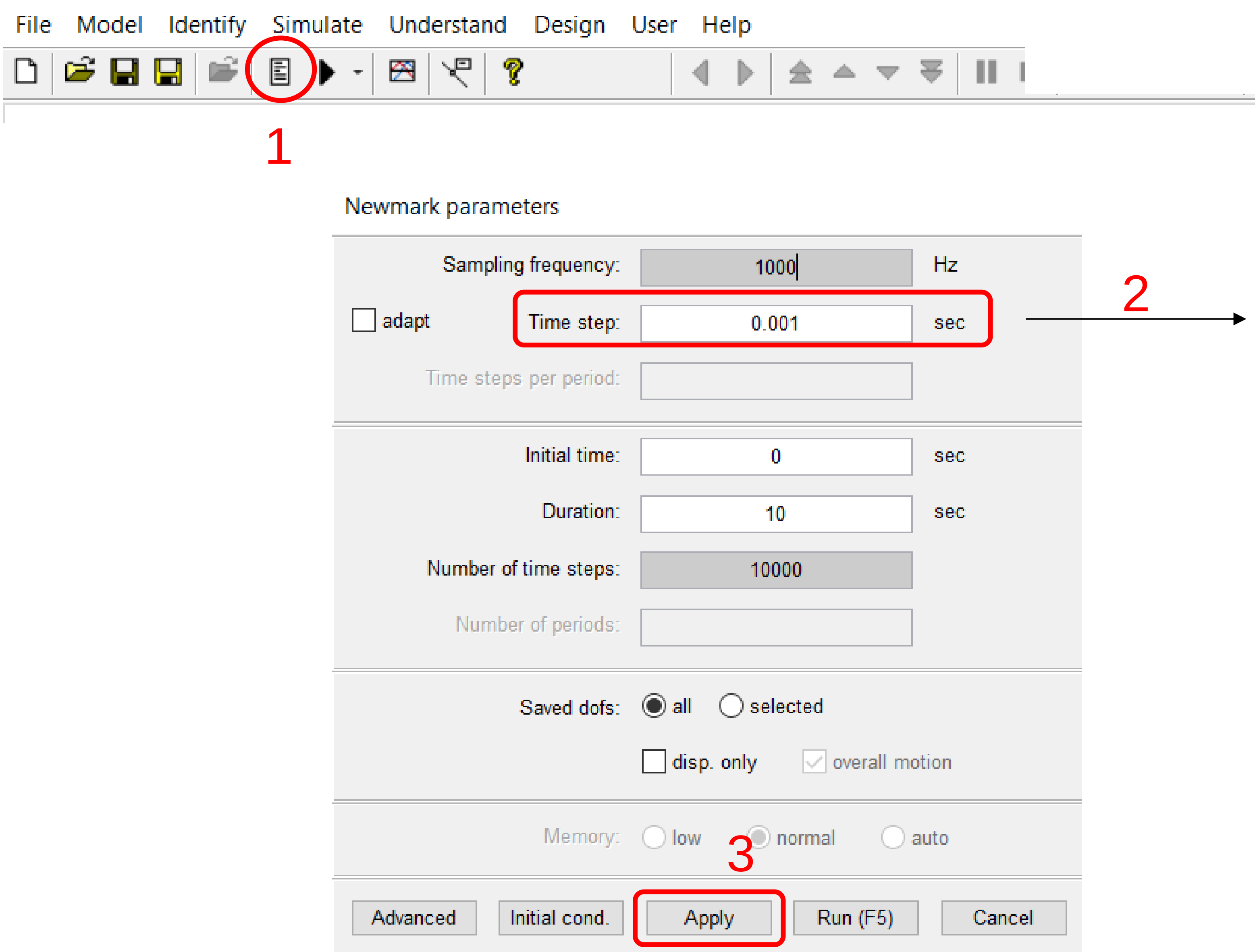
Right click on the curve



Compare the curves

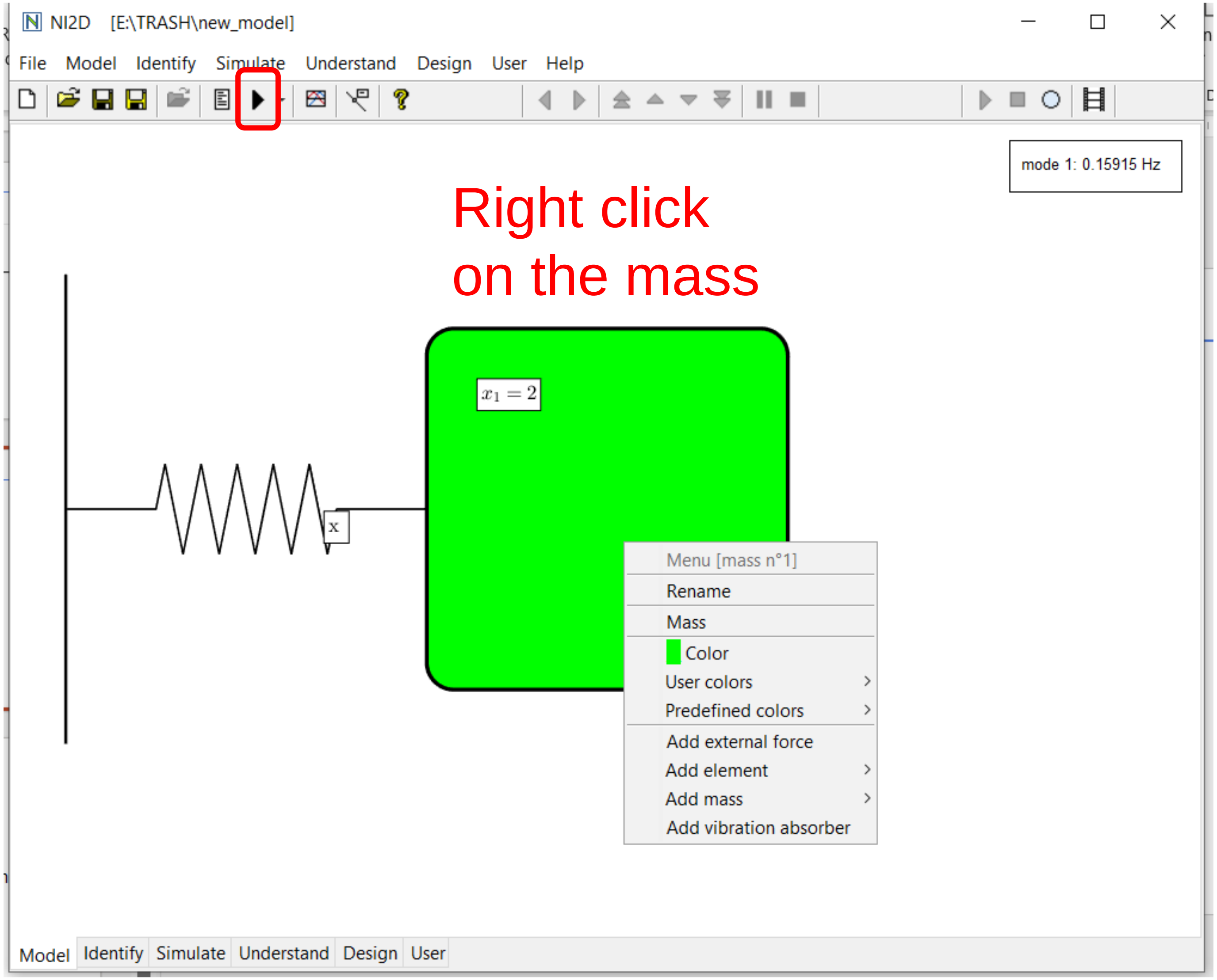


Select an inadequate time step



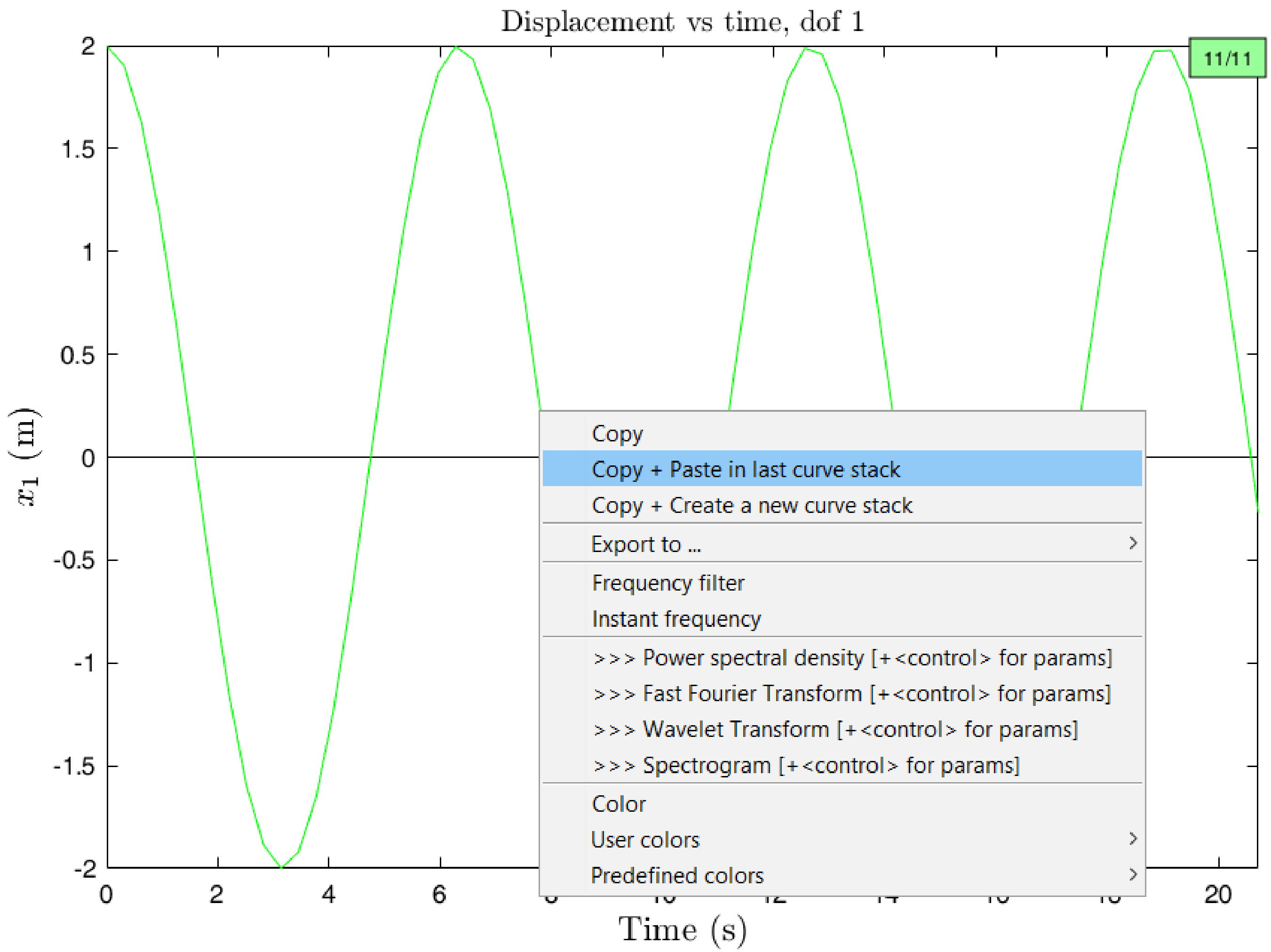
0.314 sec (20 points per period)

Change the color and run

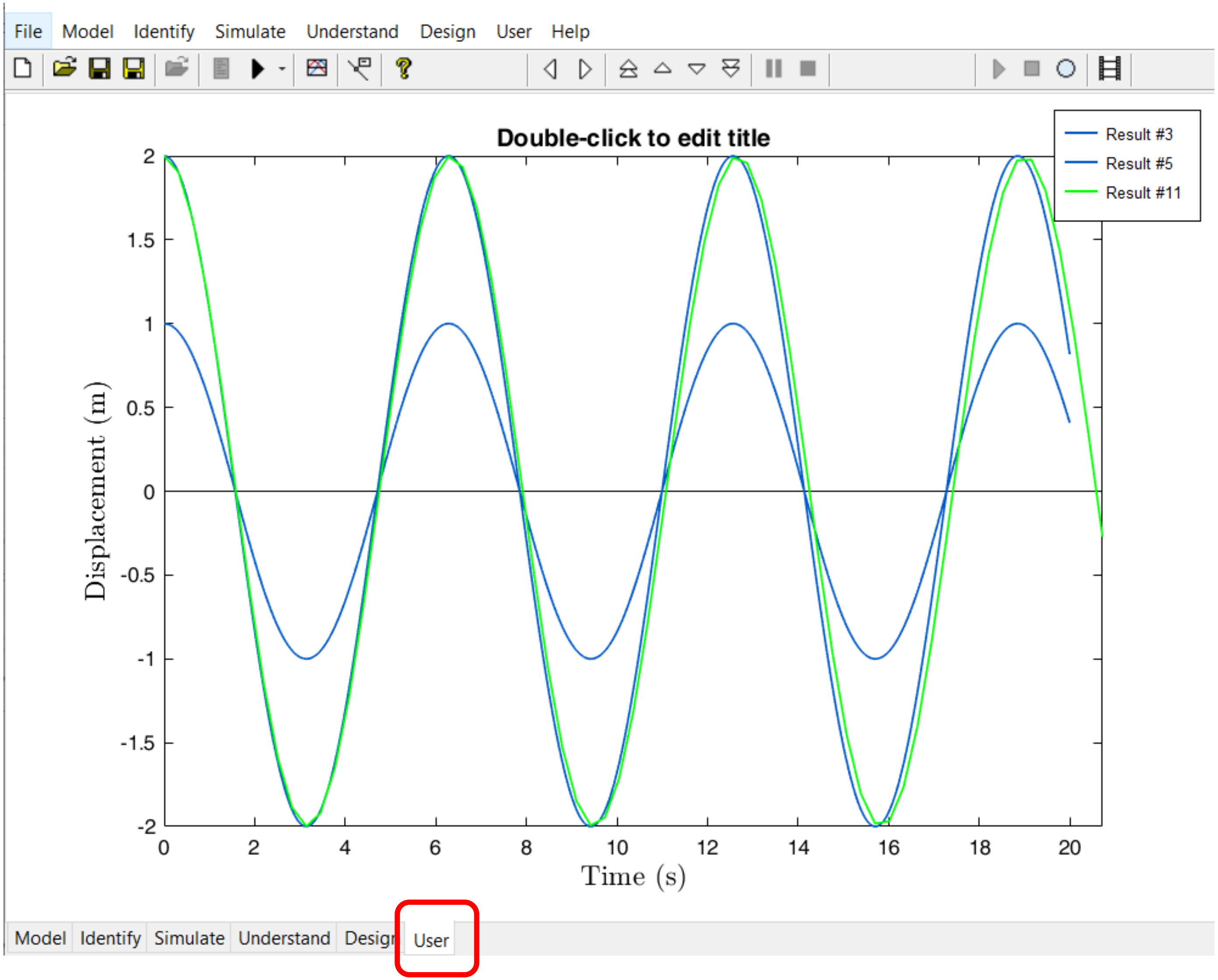


Send the result to the user tab

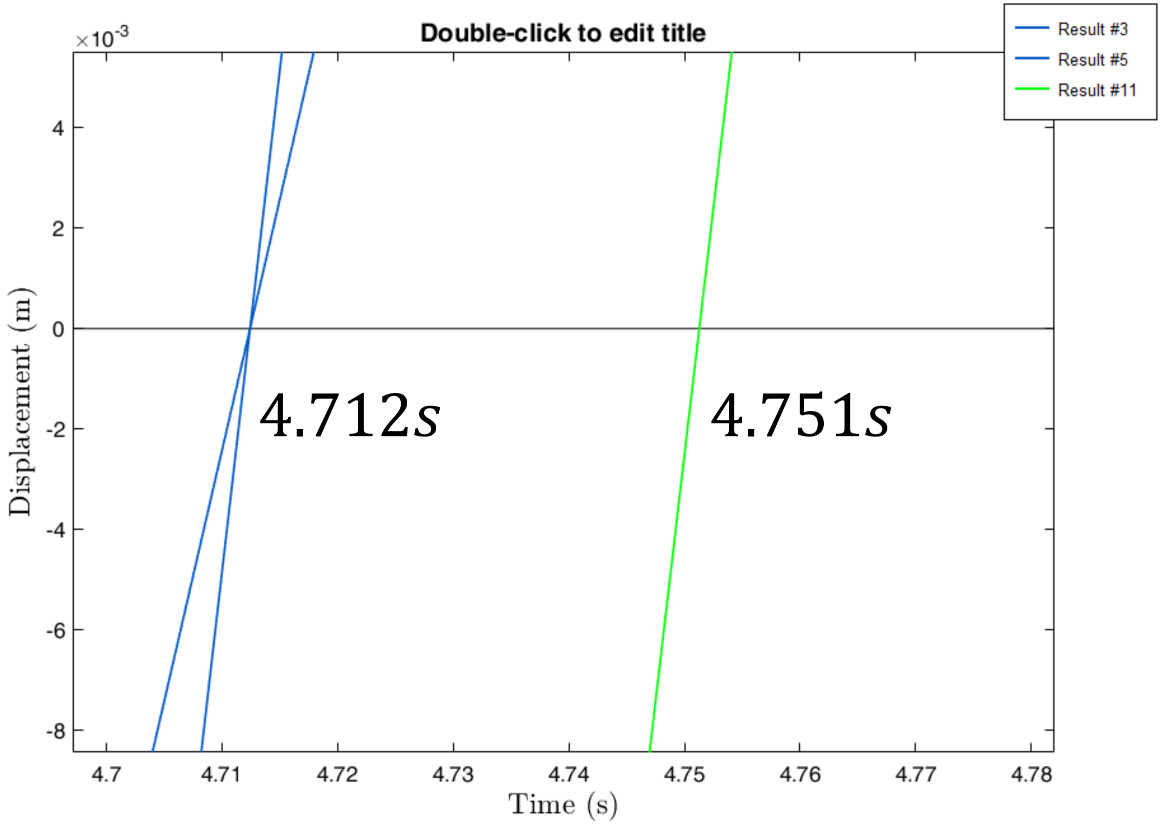
Right click on the curve



Compare the time series



And zoom (Type “r” to dezoom)



Error 20 points per period:

THEORY:

$$\frac{\omega^2 h^2}{12} \approx 0.82\%$$

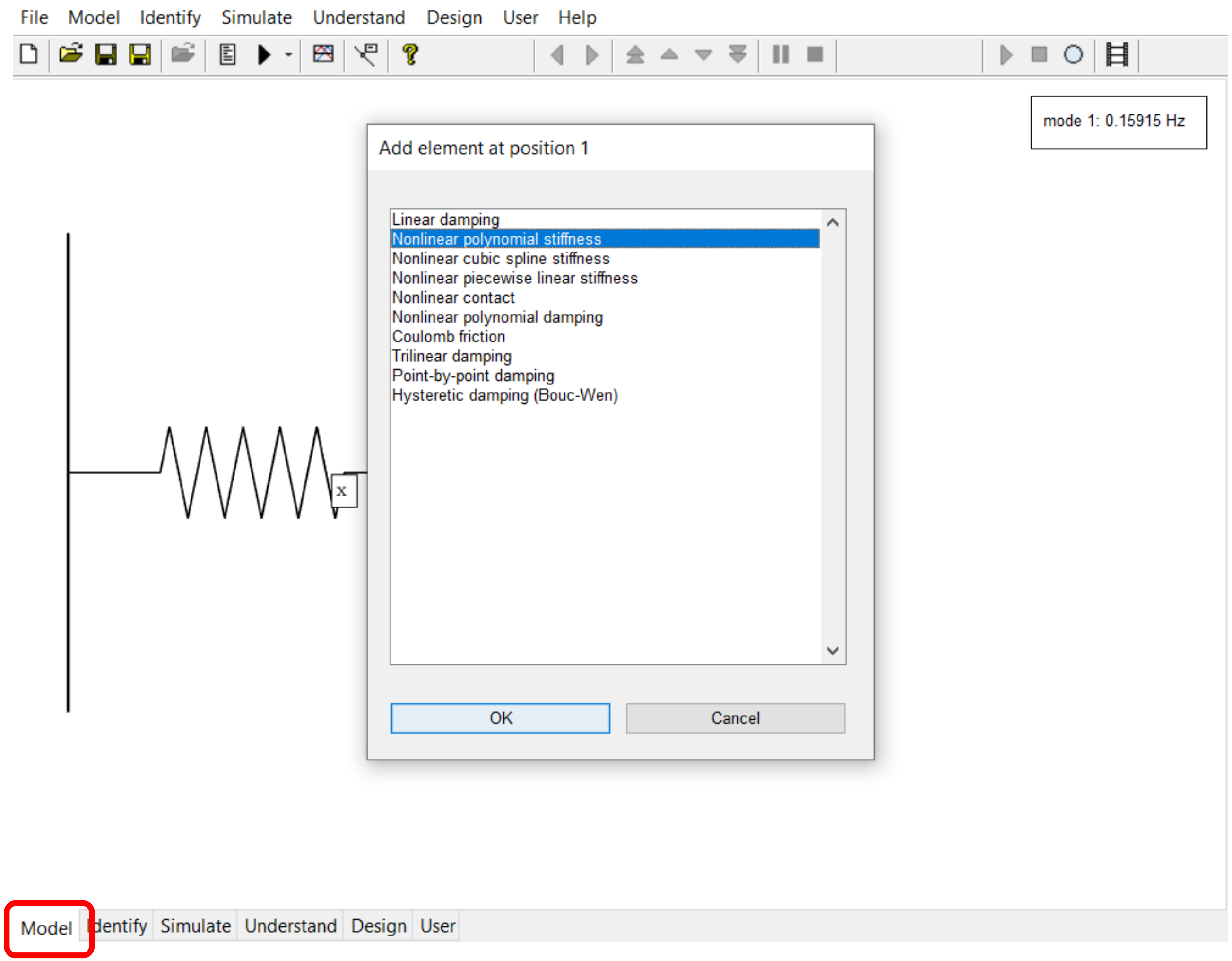
SIMULATION:

$$Error = \frac{4.751 - 4.712}{4.712} = 0.82\%$$

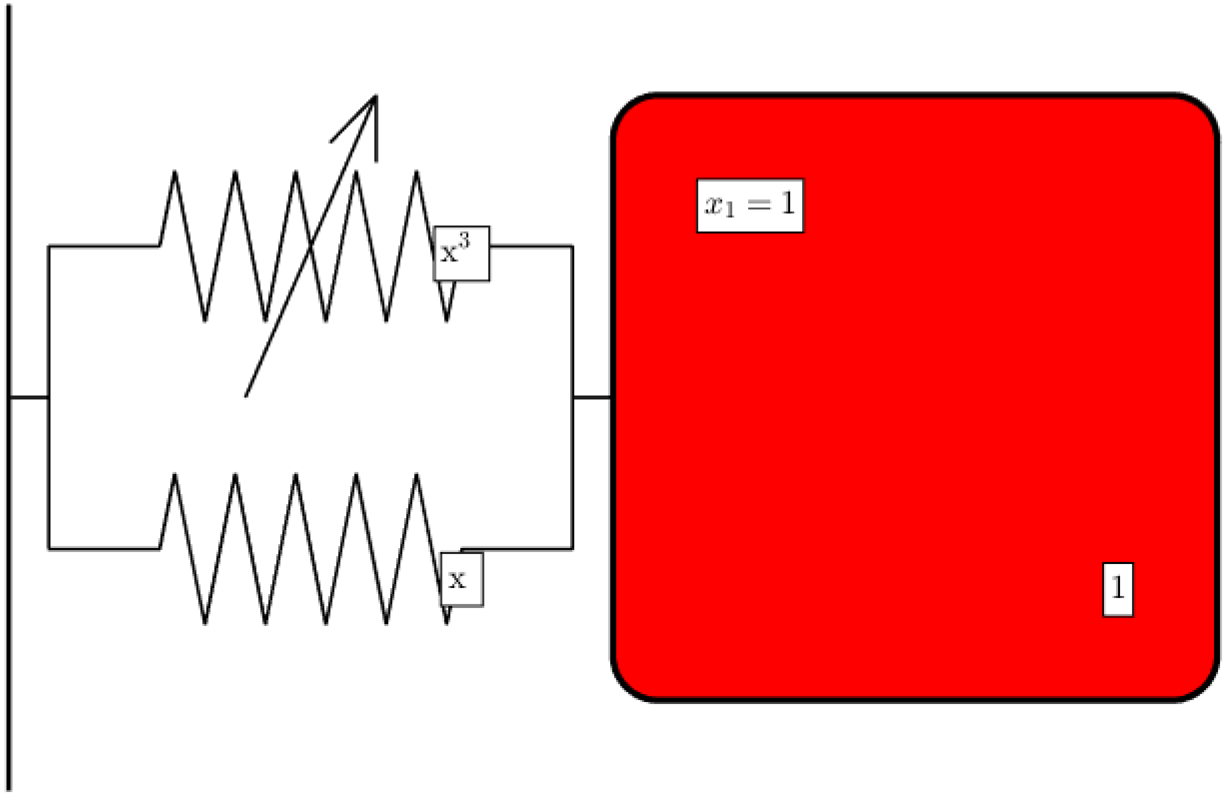
Launch your first nonlinear simulation

Introduce a cubic spring in the model (coefficient=1)

Ctrl+left click between the wall and the mass



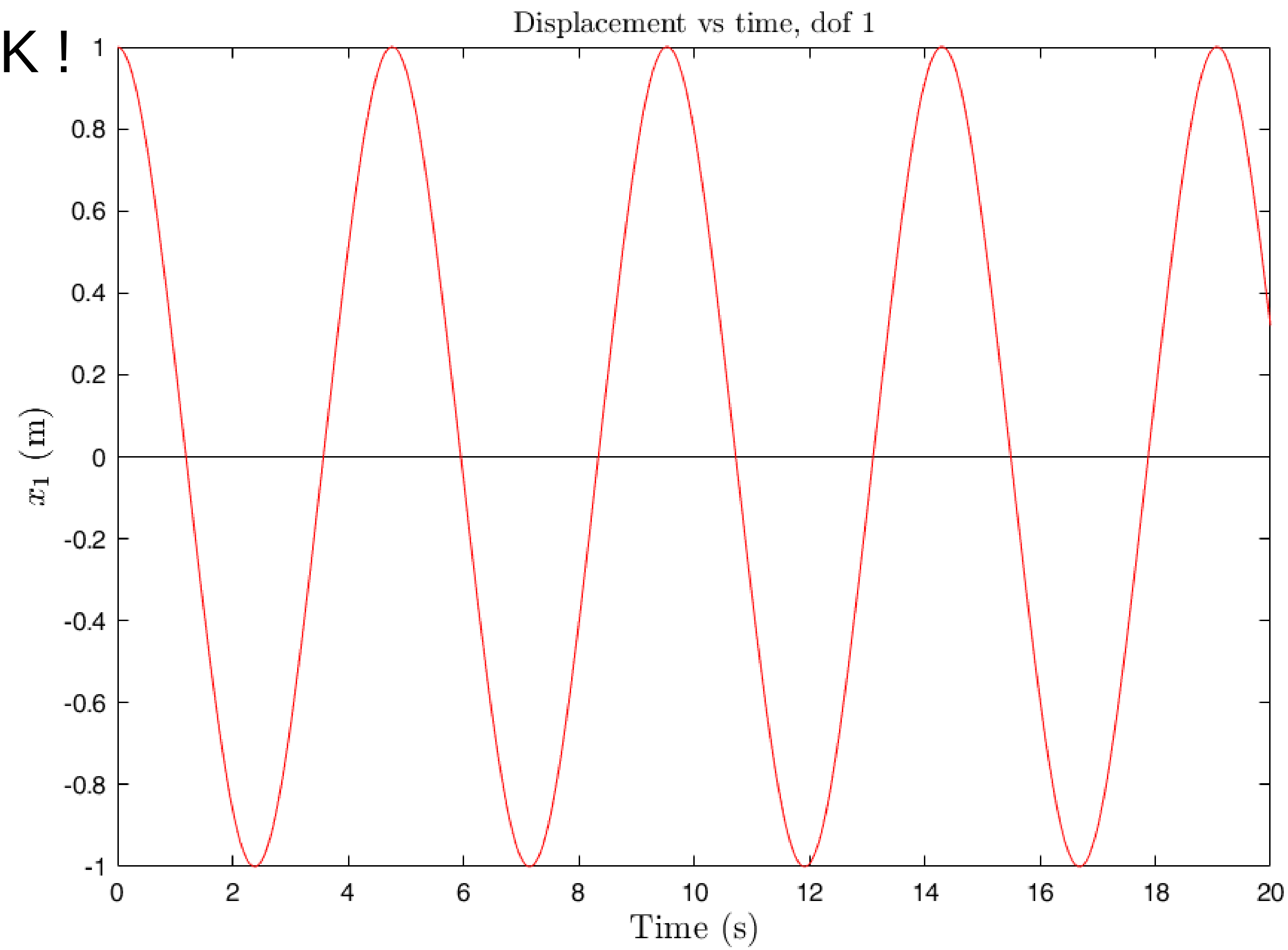
Color: red, ICdisp=1 and time step=0.01s



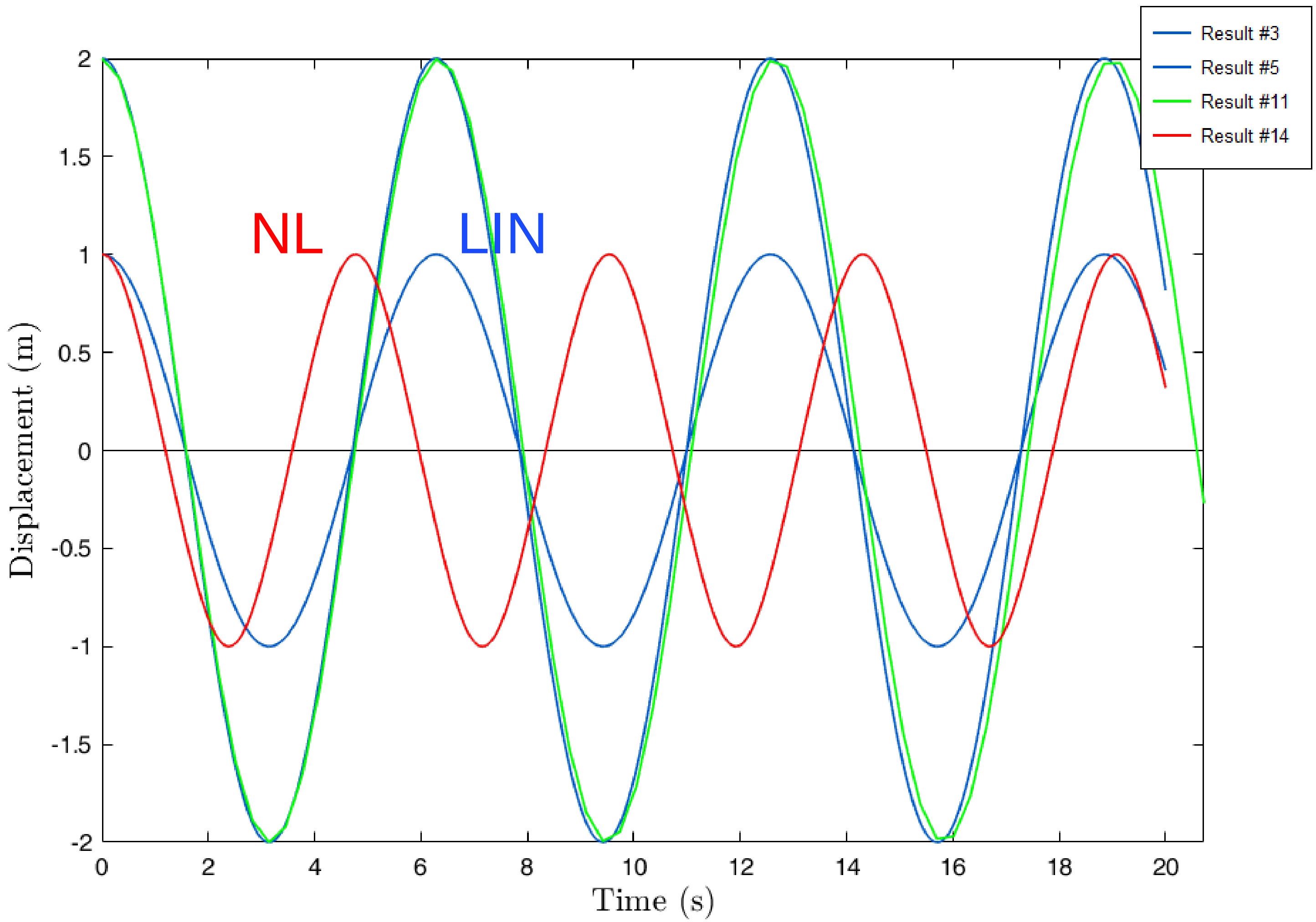
You see the hardening effect of the cubic spring

4.77s vs 6.28s

1m: OK !



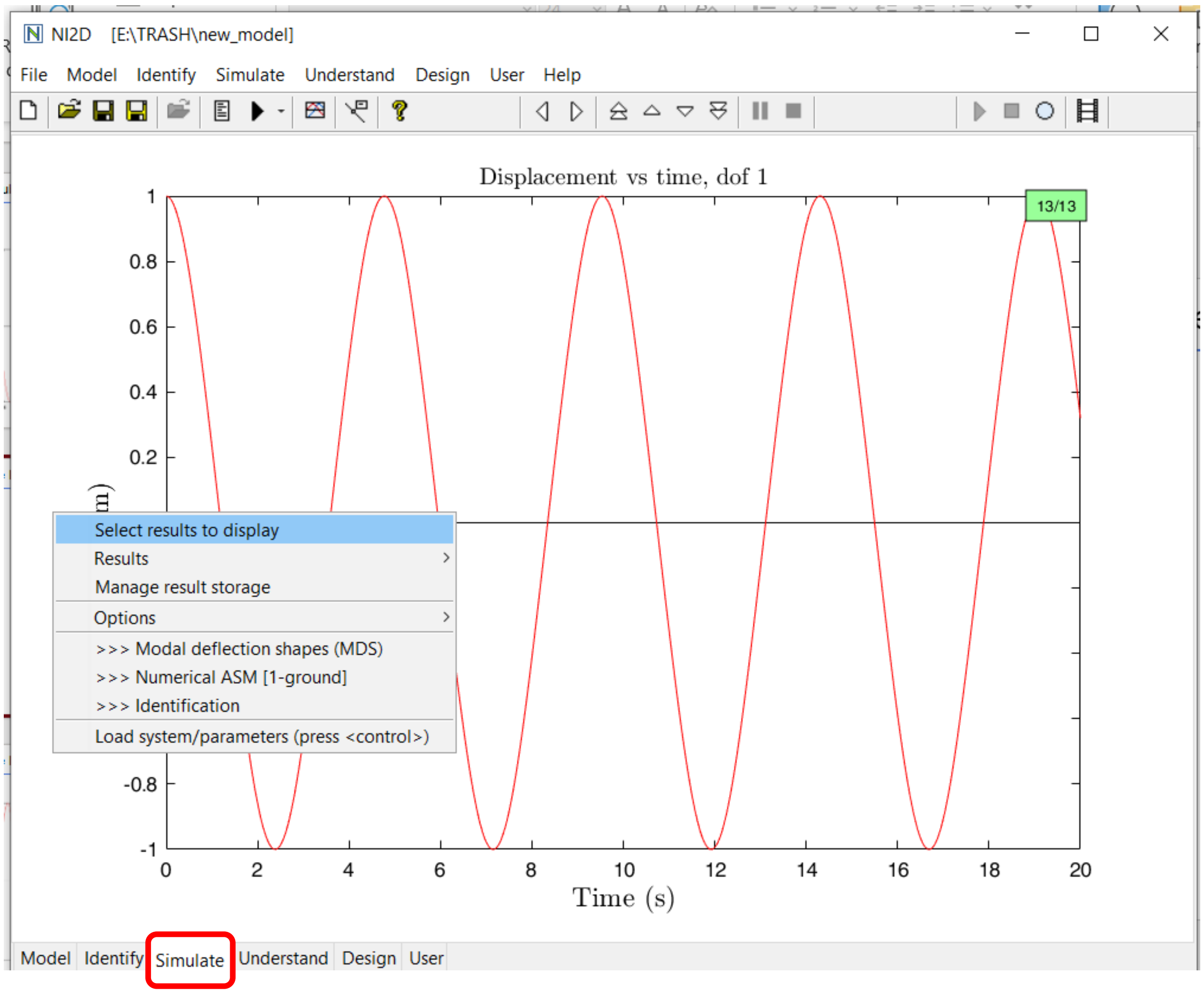
Send the result to the user tab



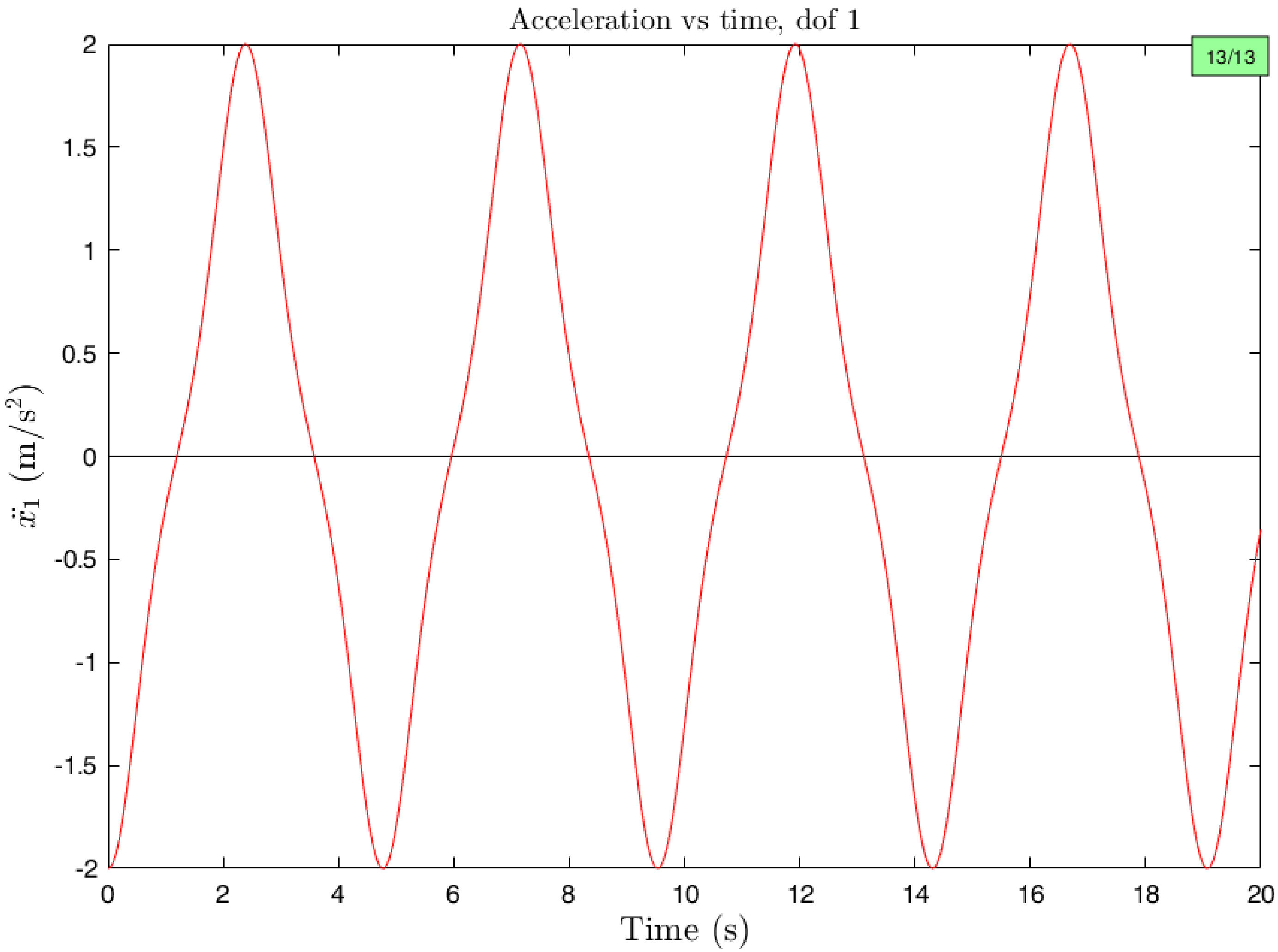
Represent the acceleration signal

Right click next to the vertical axis

Type a or z to switch between displacement and acceleration

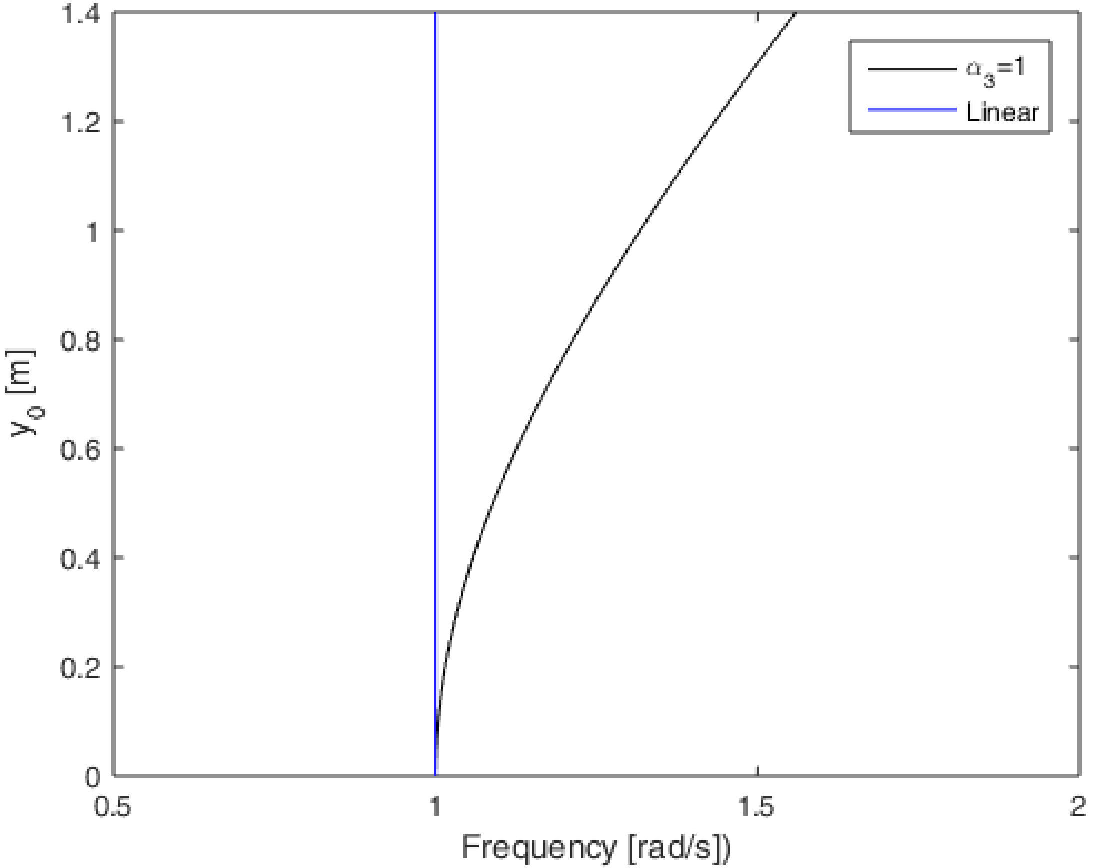


We clearly see the harmonics



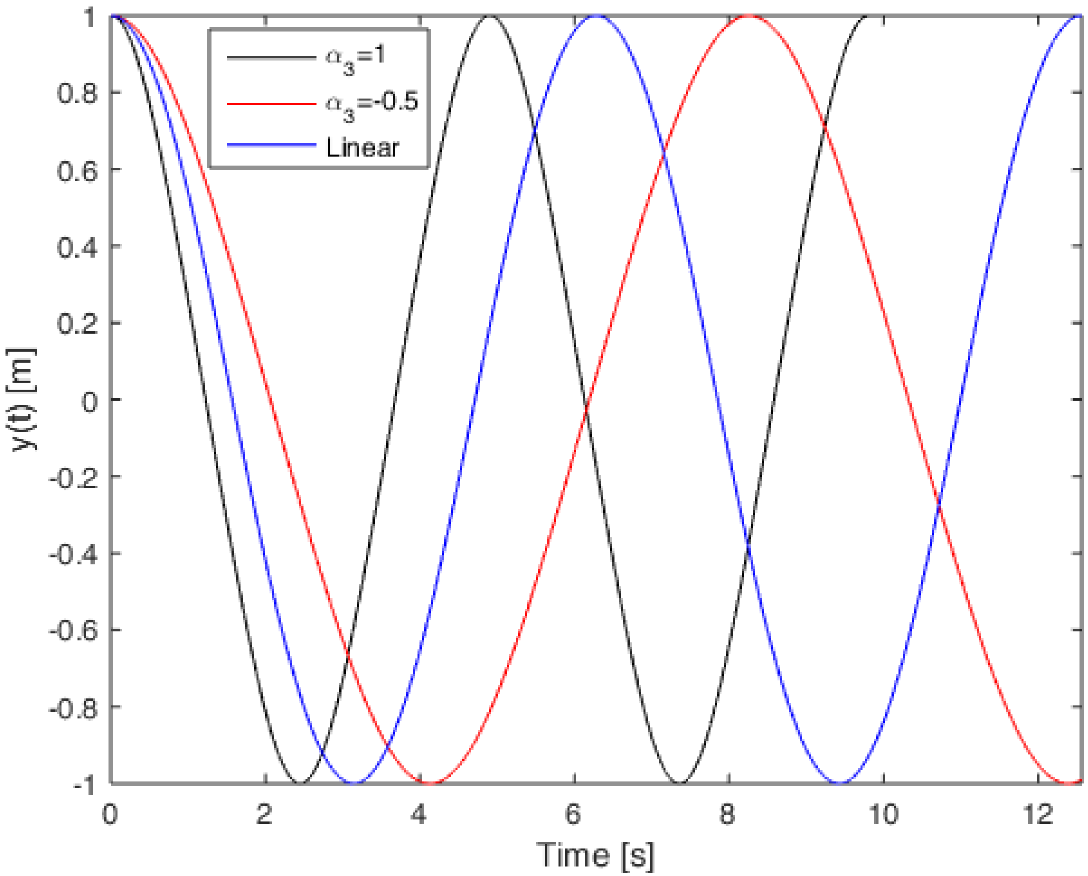
Exercice #1

Reconstruct the backbone curve by simulating the system with cubic nonlinearioty for different initial conditions



Exercice #2

Simulate a cubic spring with a negative coefficient and compare with the linear oscillator.



Exercice #3

Simulate a Helmotz oscillator.