

09-723 Proximal probe techniques.
Homework #7.

Name _____

Due by 6:30 PM, November 11, 2004

Download the homework7.zip file which contains all necessary Matlab files by clicking on it and choosing to save it on your computer (e.g. on your desktop). Open the archive on your computer and extract it to some folder. Make sure that a path is set in Matlab to this folder. To set a path, choose the set path option in the file menu of Matlab. Click the Add with subfolders button and locate the folder to be added to the path in the pop-up window and click OK. Then click Save and Close.

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Dynamic Mode Model (Some assembly required)

All necessary parameters are entered through the provided Graphical User Interface (GUI), which also controls the execution of the Simulink model, which you will need to construct in Simulink, with some minor adjustments to your model from the Midterm. Save the new model as **ForceCurveModelDMT_2.mdl**. Do not save over your old model. Save the model in the folder that you extracted the contents of **Homework7.zip** into. You should have already set a path to this folder. Make sure that in your model you call the variables as follows:

Mass: M_{tip} (As promised in previous homework, this is now the mass of the tip)
Spring constant: K_{spring}
Damping Coefficient: B_{damp}
The simulation step (Fixed-step size): $SimStep$
The total simulation time (i.e. Stop Time)= $SimTime$
The initial velocity = Z_{prime} (initial condition for the first integrator)
The initial position = Z_{start} (initial condition for the second integrator and the drive offset)
The position trajectory = Z_{traj}
The time = $time$
The driving force amplitude = F_0
The drive frequency (operating frequency in Hz) = F_{oper}
The phase = Φ_i
The potential energy = P_{energy}
The kinetic energy = K_{energy}
The damping power = B_{power}
The damping energy = B_{energy}
The drive power = D_{power}
The drive energy = D_{energy}
The ramp stop distance = Z_{end}
The ramp position = $RampPos$
The Hamaker constant = A_{tip}
The tip radius = R_{tip}
Sigma = σ
The Lennard Jones force = FLJ
The ramping rate = $RampRate$
Indent constant = $IndentConst$
 $a_{DMT} = a_{DMT}$

If these names are not used, the GUI will not work.

All other variables will be defined through the GUI.

Here are some hints for constructing the model:

- I. Make sure your model uses a fixed step.**

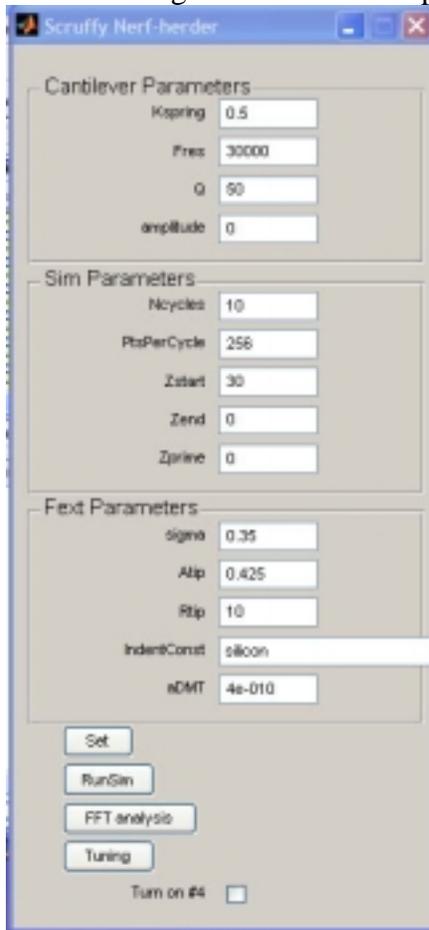
In the **Simulation** menu, select **Configuration Parameters. . .** and set **Type:** to **Fixed-Step**, and **Solver:** to **ode4 (Runge-Kutta)**, and **Fixed-Step Size** to **SimStep**.

- II. Make sure you use the **DMT potential for sphere and a surface.**
- III. Add the set of blocks calculating the amplitude (more specific instructions are being sent to everybody via e-mail).
- IV. Make sure that the drive is scaled by **0.5(Kspring/Mtip)**

Before running the model you need to provide the values of other parameters using the provided GUI. To use the GUI provided, run `Homework7` from command line.

>> Homework7

The following interface should appear:



Fres – define your desired resonance frequency in Hz, the GUI will use this and Kspring to determine Mtip, etc.

Q – the quality factor of the cantilever.

amplitude – the desired free amplitude of the cantilever in tapping mode (set it to zero for contact mode force curves)

Ncycles – this is scaled in Q cycles now, i.e. the number of cycles is Ncycles times Q.

Zstart – defines the starting and ending distance from the surface (in nm). For tapping mode, the distance is measured from the bottom of the oscillation

Zend – define force curve depth (in nm). For tapping mode, the distance is measured from the bottom of the oscillation.

IndentConst – select the sample material, and the GUI will generate the proper indentation constant.

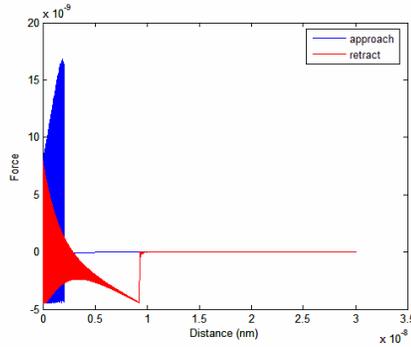
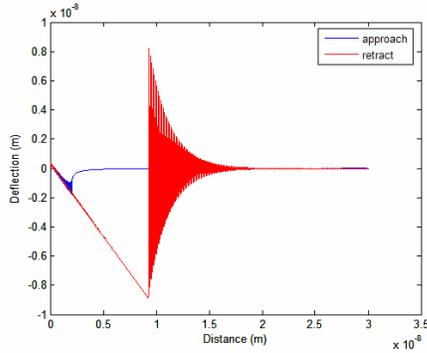
Set – sets parameters, needs to be run before simulations.

Run Sim – run the sim

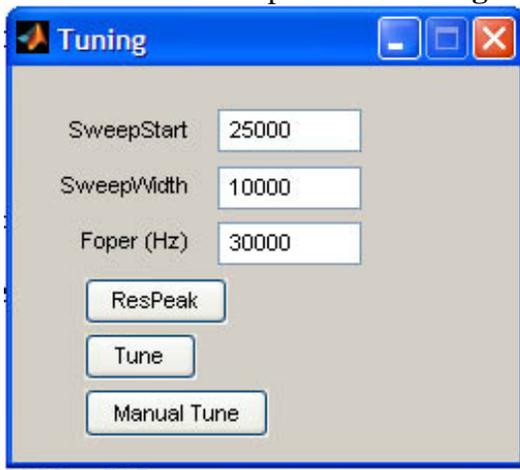
FFT analysis – Runs Fourier transform.

Tuning – opens the cantilever tuning menu. In tapping mode, the cantilever will need to be tuned before running a simulation.

Click the **Set** button and then the **Run Sim** button and the following plots should appear (this may take a few minutes as there are several calculations being performed):

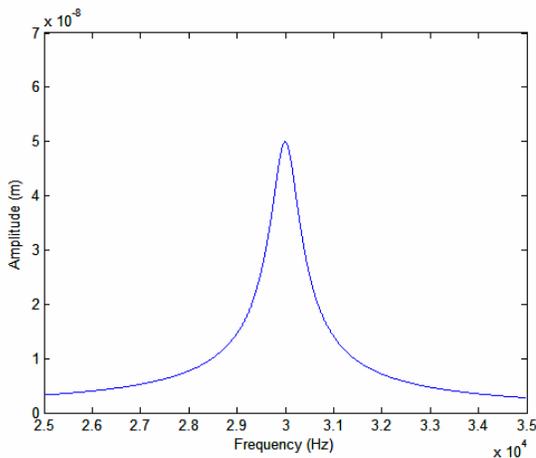


For non-contact mode simulations, you will need to tune your cantilever. Change the **amplitude** to a positive value (try 50 to get the exact same plots shown later) and click the **Set** button. Now press the **Tuning** button. The following GUI should appear:



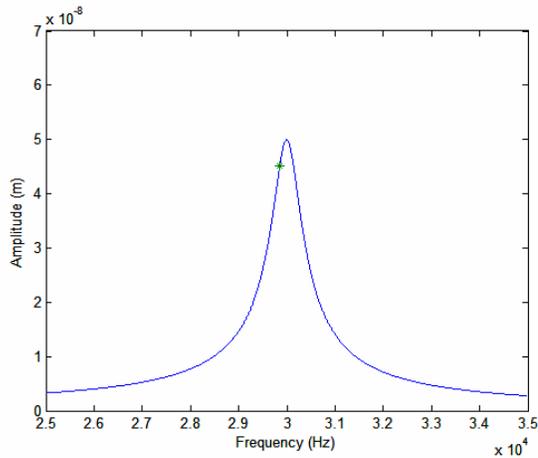
SweepStart – defines the starting frequency (in Hz) for plotting the amplitude resonance of the cantilever.
SweepWidth – defines the sweep size in Hz for plotting the amplitude resonance of the cantilever.
ResPeak – plots the free amplitude of a cantilever as a function of frequency (Hz)
Tune – prompts for the percent off resonance desired for the operating frequency and if the user wishes to operate above or below resonance. The new Foper will be displayed in the box on this GUI labeled Foper (Hz).
Manual Tune – may or may not read a value you typed into the box for Foper. I haven't completely debugged it yet. You do not need it for this homework assignment. You can test it out if you want. If you do, let me know if it works.

Click the **ResPeak** button. The following plot should appear:

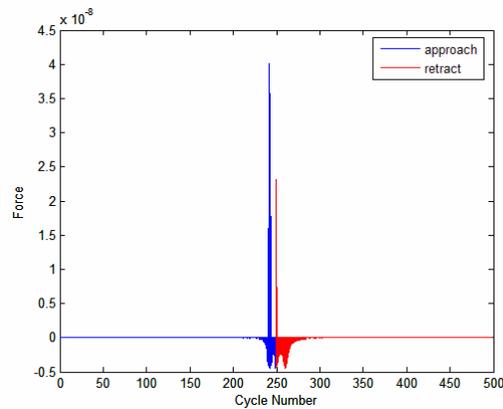
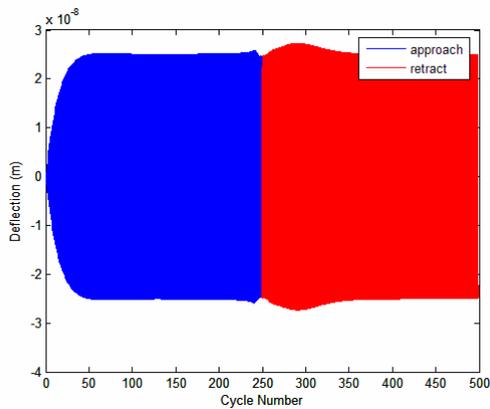


Now, click the **Tune** button. The first prompt will ask for the “% off resonance”. This is to decide what percentage off resonance you wish to operate. Enter **90** and click **OK**. The second prompt will ask “below(1) or above (2)?”. This is to determine if you wish to

operate above or below resonance, i.e. enter a 1 for below or a 2 for above. Enter **1** and click **OK**. The following plot should appear:



The green ‘*’ indicates where on the resonance peak you are operating. The **F₀** is automatically adjusted to maintain the value of **amplitude** that was entered in the first GUI. Click **RunSim** on the first GUI, and the following plots should appear:



Do not press set after tuning. Notice that the approach and retract are no longer plotted on top of each other. This is to make it easier to see them separately. Also, the x axis is scaled in Cycle Number, which is the number of cycles in the simulation (**Ncycles * Q**). **If you want to run the sim again, you will need to press the Set button and then the Tune button (entering the same values) again.** If you don't change any of the **Cantilever Parameters: Kspring, Fres, Q, and amplitude**, you will not need to rerun **ResPeak**. If you did change them, you will need to rerun **Respeak**, and depending on what you changed, you may need to adjust **SweepStart** and **SweepWidth**. If you change any parameter on the main screen, you will need to press **Set** before running a new simulation and retune the cantilever. If **amplitude** is zero, you do not need to tune the cantilever.

Problems

Illustrate your answers with appropriate graphical outputs of simulations.

1.1 First, you will be verifying the frequency shift of a cantilever in the presence of external force

Set **Kspring** = 0.5, **Fres** = 30000, **Q** = 50, **amplitude** = 10, **Ncycles** = 5, **PtsPerCycle** = 256, **Zstart** = 5, **Zend** = 5, **Zprime** = 0, **sigma** = 0.35, **Atip** = 0.425, **Rtip** = 10, **aDMT** = 4e-10, and **IndentConst** = silicon

Using a step excitation of a cantilever and Fourier analysis (**FFT Analysis** button), verify the shift of the resonance frequency of the cantilever in the presence of external force. Do this by changing the values of **Rtip** and **Atip**. (note: to perform the analysis in the absence of external force, set **Atip** = 0) To create the step excitation, change the **initial conditions** of the second **integrator** of the harmonic oscillator loop to **Zstart + Zstep**. You will need to provide the value of **Zstep** from command line, make sure that it is in the range of few nm, and does not too large, otherwise the tip will strike the surface. You can prevent the tip from striking the surface by adjusting the height of the cantilever above the surface i.e. changing **Zstart** and **Zend** (they should still be equal to each other, otherwise you will be running a force curve experiment) or by using a smaller **Zstep**.

1.2 Now explore what happens to cantilever amplitude when operated above and below resonance in the presence of external force

Note: for problems 1.3-1.5, either set **Zstep** = 0 from command line or remove it from the model.

1.3

Set **Kspring** = 0.5, **Fres** = 30000, **Q** = 50, **amplitude** = 20, **Ncycles** = 10, **PtsPerCycle** = 256, **Zstart** = 15, **Zend** = 1, **Zprime** = 0, **sigma** = 0.35, **Atip** = 0.425, **Rtip** = 10, **aDMT** = 4e-10, and **IndentConst** = silicon

Run force curves at operating frequencies 90% above and below resonance. What happens to the tip amplitude under both conditions? What would be the implication of your observations on the choice of operating conditions for non-contact AFM?

1.4

Set **Kspring** = 0.5, **Fres** = 30000, **Q** = 50, **amplitude** = 20, **Ncycles** = 10, **PtsPerCycle** = 256, **Zstart** = 10, **Zend** = 10, **Zprime** = 0, **sigma** = 0.35, **Atip** = 0.425, **Rtip** = 10, **aDMT** = 4e-10, and **IndentConst** = silicon

This time you will be running the “mystery” problem, and your task is to propose what is causing the observed cantilever behavior. In order to set the GUI to activate this problem, click check box **Turn on #4** on the GUI.

Press the **Set** button, tune your cantilever to some frequency above resonance (e.g. 50%), then **RunSim**. Observe cantilever deflection, amplitude and Force trajectories.

Repeat the simulation below resonance.

Propose what causes the observed behavior.

1.5

Set **Kspring** = 0.5, **Fres** = 30000, **Q** = 50, **amplitude** = 20, **Ncycles** = 10, **PtsPerCycle** = 256, **Zstart** = 15, **Zend** = 1, **Zprime** = 0, **sigma** = 0.35, **Atip** = 0.425, **Rtip** = 10, **aDMT** = $4e-10$, and **IndentConst** = silicon

Make sure that the check box for question 1.4 is turned off. Run a force curve at operating frequency 50% below resonance. Explain what happened to the cantilever amplitude? What changes are there in the force plot when compared to the force plots produced in question 1.3?