09-723 Proximal probe techniques.   Name_____

Midterm Exam part II
(60 % of total midterm grade)

Due by 6:30 PM, Thursday October 26, 2004

Please note that you need to work independently on all exam problems. No collaboration is allowed.

Download the Midterm.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.

If any questions need clarification or if you experience any technical problems, please contact Justin at:

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The Midterm GUI will work with your model from homework 6 (as this GUI reuses some of the m-files and models form homework 6, make sure that it is still in Matlab's path). Before running the model you need to provide the values of other parameters using the provided GUI. To use the GUI provided, run `Midterm` from command line.

`>> Midterm`

The following interface should appear:
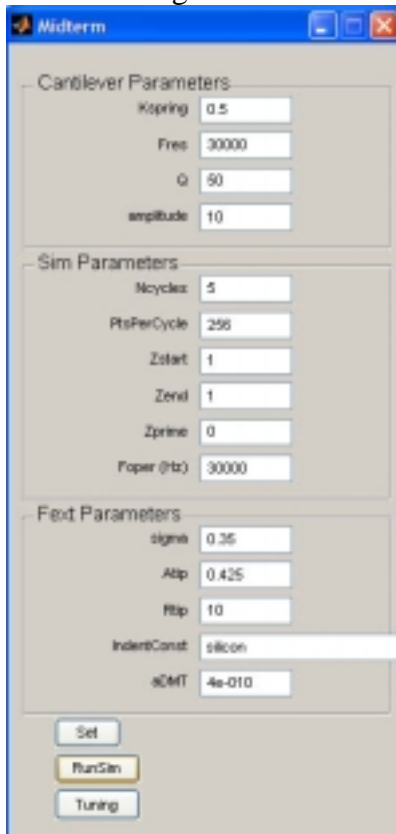
Fres – define your desired resonance frequency in Hz, the GUI will use this and Kspring to determine Mtip, etc.
Q – the quality factor of the cantilever.
amplitude – the desired free amplitude of the cantilever in tapping mode (set it to zero for contact mode force curves)
Ncycles – this is scaled in 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.
Foper – set the operating frequency.
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
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 **RunSim** button and the following plots should appear (this may take a few minutes as there are several calculations being performed):
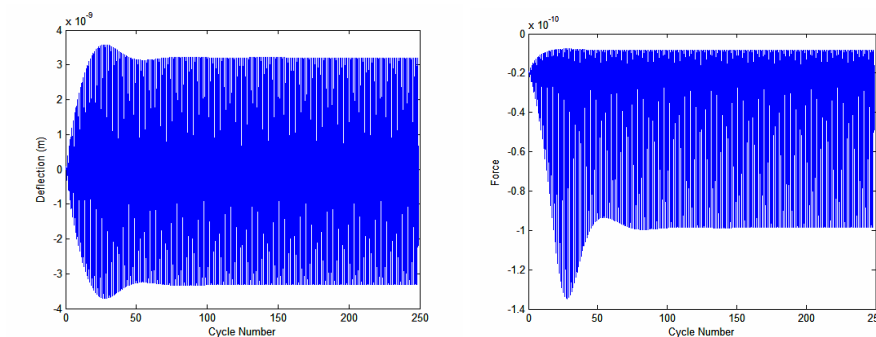
Make sure that whenever you change a parameter that you press **Set** before **RunSim.**

Problem 1

Perform described calculations and answer <mark>highlighted questions</mark>

*In this problem, you will be exploring what happens when you drive a cantilever near the surface in the presence of attractive potential. You will discover that cantilever resonance conditions change in certain fashion. Your goal is to determine how this change depends on **Atip** and **Rtip**, and based on your observations propose an explanation of observed effects.*
> Set **Kspring** = 0.5, **Fres** = 30000, **Q** = 50, **amplitude** = 5, **Ncycles =** 5, **PtsPerCycle** = 256, **Zstart** = 6, **Zend** = 6, **Zprime** = 0, **sigma** = 0.35, **Atip** = 0.425, **Rtip** = 10, and **aDMT** = 4e-10
>
> Start with the conditions above. With **Zstart** and **Zend** equal to 6, the model will maintain the resting position of a tip and cantilever base at 6 nm.

*Just as you did it in one of the previous homework assignments on harmonic oscillator, determine the position of the amplitude resonance peak for different values of Hamaker constant **Atip** and tip radius **Rtip**. In particular, determine the relationship between **Atip, Rtip** and the product of **Atip** and **Rtip** and the observed resonance frequency. (Hint: with proper planning, this can be accomplished with mapping just 4 resonance peaks.) For this part, you can safely change the values of **Atip** and **Rtip** by up to a factor of 4.*

<mark>**1.1** (**20 points**) Describe what happens to the resonance peak with changes in **Atip** and **Rtip.**</mark>

<mark>**1.2** (**5 points**) Based on the dependence of the resonance frequency on **Atip** and **Rtip,** propose what causes the observed effect.</mark>

<mark>**1.3** (**5 points**) Propose how the observed effect could be used in AFM imaging.</mark>

*For a constant value of **Atip**, and fixed values of other parameters, carry out a series of calculations for progressively larger values of **Rtip** until you notice that the deflection and force plots show <u>dramatically</u> <u>different</u> behavior.*

<mark>**1.4** (**10 points**) Based on your experience with contact mode force curves, explain what is the reason of this drastic change of behavior above certain value of **Rtip**.</mark>

Problem 2

Perform described calculations and answer <mark>highlighted questions</mark>

*Change the contact mechanics portion of the DMT force in the Expression box of the 2nd **Fcn** block to model a conical indenter instead of a spherical indenter.*

<mark>**2.1** (**15 points**) Verify that your changed model simulates a conical indenter by Force Curve analysis (just as in one of the previous homework assignments).</mark>

<mark>**2.2** (**5 points**) Why is this new force not fully accurate for a conical tip? (Hint: look at the non-contact portion of the force.)</mark>