ME59700/PHYS57000 Fundamentals of AFM Fall 2009

Course Description: A three-credit course for students interested in learning the fundamentals underlying Atomic Force Microscopy.

Instructors: A. Raman; Office: ME 365/BIRCK 1019 and R. Reifenberger; Office: PHYS 80/BIRCK 1015

Instructors: 9:00 a.m.-10:15 a.m. every Tuesday/Thursday in ARMS B071. Questions are encouraged before, during or after any lecture. Notecard questions are also welcome.

Office Hours: A. Raman (2.00-3.00 PM Mondays, Fridays, Rm 362, ME Bldg), R. Reifenberger (Tuesdays 10.30-11.30 AM, Rm 80, Physics Building).

Prerequisites: The following background is recommended: (a) undergraduate-level mechanics (Statics, Dynamics, Mechanics of materials.) at the level of (PHYS 310) or (ME 270, ME 274, ME 323 combined); (b) undergraduate-level ordinary and partial differential equations, (c) basic electromagnetism at the level of PHYS 330, and (d) introductory quantum mechanics at the level of PHYS 550.

Course Web Page: All assignments, course materials, grades, notifications are posted on Blackboard http://www.itap.purdue.edu/tlt/blackboard/index.cfm
Please do not email the instructors directly, instead use the mail function on the course website on blackboard. Also if your question is not personal please consider putting it on the "Discussion" string so everyone can see the question and our response to it.

Text: There is really no required textbook for the course. A lot of the material is covered in the *course reader* – a selection of key review and historical articles. Besides the reader and the class notes, here are some books that we recommend:
[1] C. Julian Chen, I*ntroduction to Scanning Tunneling Microscopy*, 2nd Edition (Oxford University Press, Oxford) 2008.
[2] J. Israelachvili, Intermolecular and surface forces, second edition, (Elsevier), 1991.
E. Meyer, H. J. Hug, R. Bennewitz, *Scanning Probe Microscopy – the lab on a tip* (Springer-Verlag) 2003.
[3] D. Sarid, *Scanning Force Microscopy: with applications to electric, magnetic and atomic forces*, Oxford Series in Optical and Imaging Sciences, (Oxford University Press, Oxford) 1994.
[4] V. J. Morris, A. P. Gunnig, A. R. Kirby, *Atomic Force Microscopy for Biologists* (World Scientific) 1999.

Assignments: The approximate homework schedule is given on the class syllabus. A reading list of published journal articles will be provided as the semester unfolds. **This material should be read before attending lecture.** Students who have read the assigned material prior to class will find the lecture far more meaningful.

Exams: No exams are scheduled for this course.

Homework Assignments: There will be approximately five homework assignments with a total of 15 homework problems. Many of the homework problems will require the use of on-line simulation programs. Each homework problem will be worth 10 points each. The five homework assignments will cover i) Quantum tunneling and density of states; ii) Force vs. distance in static AFM; iii) Cantilever dynamics; iv) Dynamic AFM; v) Frequency modulated AFM.

Reading Assignments: Throughout the semester, you will be required to read research papers (both in the reader and others that we may hand out) that describe the seminal advances in STM and AFM. *Please see reading assignments in the lecture and reading schedule on next page*. You are supposed to start reading the material before coming to the corresponding class.

Term Project: Each student will be required to choose a topic related to this course material for a final written report *and* an oral presentation at the semester's end. A term project proposal form is provided to help you organize your term project. Term projects must be sufficiently focused so they can be accomplished during the course of a semester.

The final report will be brief (not more than 10 pages long, single spaced, 11 pt font, including all figures) and cover (a) motivations, (b) methods used, (c) results, and (d) conclusions. The oral presentation will last twenty (20) minutes. *The talk must contain no more than 12 slides and must describe the motivation, the methods and the results of your project*.

Grades: The overall grade is determined as follows: Homework 65%, Term project: 35%

Help: No teaching assistant has been assigned to this course.

Cheating and Dishonest Behavior: Dishonesty will not be tolerated during this course. Such actions are detrimental to your own development and unfair to all other students in the university. Cheating on exams, lab reports or quizzes, no matter how minor, will lead to an immediate **F** in the course and possible dismissal from Purdue.

FAQ on term projects:

How to go about proposing a term project?

Based on material covered in class, your own research, or prior research in your lab (senior students) you will probably get an idea of what4- 5 week project you want to work on. If not, start talking to the instructors early on. You need to start thinking of projects one day one. Feel free to talk to your instructors about what you are thinking. – seek their input. *You need to have discussed your proposed project with one of the instructors prior to submitting a proposal draft on Sept 29*. Please use the template provided below to propose your term project. We will provide you feedback on your proposal and your final proposal is due Oct. 8/ We expect you to work on this project from Oct 8- Nov 19. Plan for a 5 week project including time to write your report, so it needs to be very focused.

How to write the project report?

After completing most of your project by Nov 19, your written project reports are due Nov 24 in class. *The final report will be brief (not more than 10 pages long, single spaced, 11 pt font, including all figures) and cover (a) motivations, (b) methods used, (c) results, and (d) conclusions.*

How to prepare for my oral presentation?

The oral presentation will last twenty (20) minutes. *The talk must contain no more than 12 slides and must describe the motivation, the methods and the results of your project*. You can use your own computer or tell us and we will provide one. The presentation will be made on the computer using powerpoint or similar software.

ME 59700/PHYS57000 Template Term Project proposal Fall 2009

(1 page proposal)

My Name: Jane Doe
My Department/School: School of critter studies
Proposed title: Can critter chew through AFM chips?

Why is this interesting/relevant to me? (One paragraph)

Project goals: (aka *the what's*?)one or two goals, bulleted list

- To understand…,
- To explore…., to study….

Methodology: Be as precise as possible (*aka the how's?*), long itemized list.

1. I will study section 3.3 of the journal papers XX, YY, and ZZ
2. I will use VEDA to simulate ??
3. I will recreate using VEDA the Figures AA, and BB in this journal paper
4. I will prepare a sample using? (and if I have done it before)
5. I will make the following measurements

Reference list: Type up a short list of journal papers/books that you will read.

Grading (or how do I want the instructors to grade my project report):
For reading up what I proposed: XX%, For recreating figure ?? using VEDA: yy%
For preparing the sample: zz%, For project presentation: 20% (fixed)

Attachments: while submitting proposal where you will try to replicate published results, attach the related journal papers/references when you submit your project proposal

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ME 59700/PHYS57000 Lecture & Reading Schedule Fall 2009

Lecture	*Date*	*Subject*	*Reading*	*Instructor*	*Homework /Project*
L01-RR	Aug. 25	Course Overview and Brief Review of Quantum Mechanics		RR	
L02-RR	Aug. 27	Electronic States and LDOS		RR	
L03-RR	Sept. 1	Quantum Tunneling	Appl. Phys. Lett. 40, 178 (1982) Phys. Rev. Lett. 49, 57 (1982) J. Appl. Phys. 61, R1 (1987)	RR	
L04-RR	Sept. 3	STM experimental considerations	Appl. Phys. Lett. 50, 129 (1983)	RR	HW1 assigned
L05-RR	Sept. 8	Advanced Topics in STM		RR	
L06-RR	Sept. 10	From STM to AFM	Phys. Rev. Lett. 56, 930 (1986)	RR	
L07-AR	Sept. 15	Interaction forces-I	Butt, Capella, Kappl (reader)	AR	
L08-AR	Sept. 17	Interaction forces- II	"	AR	HW1 due
L09-AR	Sept. 22	Fundamentals of force-distance curves - I	"	AR	HW2 assigned
L10-AR	Sept. 24	Fundamentals of force-distance curves - II	"	AR	
L11-JM/DK	Sept. 29	VEDA - I	VEDA manual (reader)	JM/DK	Submit draft of term project proposal
L12-AR	Oct. 1	Contact mode and friction forces		AR	
L13-AR	Oct. 6	Free and forced vibration of point mass models; cantilever eigenmodes	Garcia and Perez (reader)	AR	HW2 due; HW3 assigned
L14-AR	Oct. 8	Calibration of cantilever stiffness; Modeling AM-AFM	Garcia and Perez (reader)	AR	Submit final draft of term project proposal
	Oct. 13	NO CLASS: October Break			
L15-JM/DK	Oct. 15	VEDA-II		JM/DK	
L16-AR	Oct. 20	Analyzing dynamic approach curves – phase and amplitude	Garcia and Perez (reader)	AR	HW 3 due, HW 4 assigned
L17-AR	Oct. 22	Analyzing dynamic approach curves – phase and amplitude	Garcia and Perez (reader)	AR	
L18-AR	Oct. 27	Imaging Force, Phase contrast	Garcia and Perez (reader)	AR	
L19-AR	Oct. 29	AM-AFM scanning, controller dynamics	VEDA manual (reader)	AR	
L20-RR	Nov. 3	Imaging artifacts in AM-AFM		RR	
L21-RR	Nov. 5	Motivation - Frequency modulation AFM		RR	HW 4 due, HW5 assigned
L22-RR	Nov. 10	Theory of FM-AFM		RR	
L23-RR	Nov. 12	Force spectroscopy in FM-AFM		RR	
L24-AR	Nov. 17	Special Topics – AFM in liquids		AR	
L25-RR	Nov. 19	Special Topics – EFM (Kelvin Force Microscopy)		RR	
L26-RR	Nov. 24	Special Topics AFM-based nanolithography		RR	Term project reports due
	Nov. 26	NO CLASS: Thanksgiving			

L27-RR/AR	**Dec. 1**	**Emerging AFM modes**		**RR/AR**	**HW 5 due**
	Dec. 3	**Student project presentations**			
	Dec. 8	**Student project presentations**			
	Dec. 10	**Student project presentations**			