ME59700/PHYS57000 Fundamentals of AFM Fall 2010

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

Lectures: 10:30 a.m.-11:45 a.m. every Tuesday/Thursday in ARMS 3115. Questions are encouraged before, during or after any lecture. Notecard questions are also welcome.

Office Hours: A. Raman (1.00-3.00 PM Tuesdays, Rm 365, ME Bldg), R. Reifenberger (Fridays 2.30-4.30 PM, 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 and quantum mechanics at the level of PHYS 330 and 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.
   J. Israelachvili, Intermolecular and surface forces, second edition, (Elsevier), 1991.
2. 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 20 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) STM and intermolecular surface forces ii) Force vs. distance in static AFM; iii) Basics of 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.

Each student will i) write a final report, and ii) make a brief oral presentation. 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 10 slides and must describe the motivation, the methods and the results of your project*.

If it is important that you learn how to use an AFM – either for use in your term project or for your future research – arrangements can be made to use a common-use AFM in the Birck Center. The AFM can be scheduled in advance and used by the hour. Training courses are available.

Dr. Xin Xu (xu55@purdue.edu) is in charge of the Scanning Probe recharge center within the Birck Nanotechnology Center and you can contact her for more information. Please be aware that your advisor and/or department must be willing to pay the nominal fees associated with the use of this center.

Grades: The overall grade will be determined as follows: Homework 60%; Term project: 35%; Attendance: 5%.

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 propose a term project?
Based on material covered in class, your own research, or prior research in your lab (senior students) you will probably have a good idea for a 4 - 5 week project you want to work on. You need to start thinking of projects from 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. 30. 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. 7. We expect you to work on this project from roughly Oct. 7 – Dec. 2. Plan for a 5 week project, including time to write your report. To do well, you need to be very focused.

How to write the project report?
After completing your project, your written project report is due Dec. 2 in class. The final report should be brief (no more than 10 pages long, single spaced, 11 pt font, including all figures, references) and cover (a) motivation, (b) methods used, (c) results, (d) conclusions, and (e) references.

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. Plan on using your own computer using powerpoint or similar software.

How will the term project be graded?
The term project will constitute 35% of your final grade. The term projects will be evaluated on the basis of 100 points as follows:

For writing a coherent review of the reading material that you identified as important: 30 points
For convincing experimental results and/or for using VEDA effectively: combined 40 points
Project presentation: 30 points

ME 59700/PHYS57000 Template for Term Project Proposal Fall 2010
(1 page proposal)

My Name:
My Department/School:
Proposed title:
Why is this interesting/relevant to me? (One paragraph)

Project goals: One or two specific goals in a bulleted list

- To understand…
- To explore….
- To study….

Methodology: Be as precise as possible. The methodology should be in the form of a 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 by……. (if you have prepared such a sample before, please elaborate)
5. I will make the following measurements…….

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

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

ME 59700/PHYS57000 Lecture & Reading Schedule Fall 2010

Lecture	*Date*	*Subject*	*Reading*	*Instructor*	*Homework/Project*
L01	Aug. 24	NO CLASS			
L02	Aug. 26	NO CLASS			
L03-RR	Aug. 31	Course Overview; Review of Quantum Tunneling; Introduction to STM	Binnig et al. [Appl. Phys. Lett. 1982 and Phys. Rev. Lett. 1982], Hansma & Tersoff (reader)	RR	
L04-RR	Sept. 2	STM experimental considerations	Binnig et al. [Phys. Rev. Lett, 1983] (reader)	RR	HW1 assigned
L05-RR	Sept. 7	Advanced Topics in STM		RR	
L06-RR	Sept. 9	From STM to AFM	Binnig, Quate, Gerber (reader)	RR	
L07-RR	Sept. 14	Interaction forces-I	Butt, Capella, Kappl (reader)	RR	
L08-RR	Sept. 16	Interaction forces- II	Butt, Capella, Kappl (reader)	RR	
L09-AR	Sept. 21	Fundamentals of F-Z, F-d curves - I	Butt, Capella, Kappl (reader)	AR	HW1 due; HW2 assigned
L10-AR	Sept. 23	Fundamentals of F-Z, F-d curves - II	Butt, Capella, Kappl (reader)	AR	
L11-AR	Sept. 28	Fundamentals of F-Z, F-d curves – III Introduction to contact mode and friction force imaging	Butt, Capella, Kappl (reader)	AR	
L12-AR	Sept. 30	Three important calibrations: Z-piezo, optical lever sensitivity, and cantilever stiffness		AR	Submit draft of term project proposal
L13-RW	Oct. 5	Experimental uncertainties in extracting elastic modulus or adhesion from F-Z curves		RW	
L14-JM/DK	Oct. 7	VEDA – I (Overview of capabilities; F-Z curve tool)	VEDA manual	JM/DK	Submit final draft of term project proposal
	Oct. 12	NO CLASS: October Break		AR	
L15-AR	Oct. 14	Intro. To dynamic AFM methods	Garcia and Perez (reader)	AR	HW2 due, HW 3 assigned
L16-AR	Oct. 14	Point mass oscillating models, linear vs. nonlinear oscillations		AR	
L16-AR	Oct. 19	Dynamic Approach Curves	Garcia and Perez (reader)	AR	
L17-AR	Oct. 21	Continuous beam models; cantilever eigenmodes	Garcia and Perez (reader)	AR	
L18-JM/DK	Oct. 26	VEDA – II (Dynamic approach and retract simulations, frequency sweep tool)	VEDA manual	JM/DK	HW3 due, HW4 assigned
L19-AR	Oct. 28	Analytical approaches – phase contrast, energy dissipation, imaging forces	Garcia and Perez (reader)	AR	
L20-AR	Nov. 4	Feedback controls in AFM; PID controller dynamics; imaging instabilities	VEDA manual	AR	
L21-JM/DK	Nov. 9	VEDA – III (Amplitude modulation scanning tool)	VEDA manual	JM/DK	
L22-RR	Nov. 11	Theory of frequency shifts		RR	HW4 due, HW5 assigned
L23-RR	Nov. 16	Implementing FM-AFM		RR	
L24-RR	Nov. 18	FM-AFM Results		RR	
L25-RR	Nov. 23	Special Topics I – Electrostatic Force Microscopy, Magnetic Force		RR	HW 5 due

		Microscopy			
	Nov. 25	**NO CLASS: Thanksgiving**			
L26-AR	**Nov. 30**	**Special Topics II – Operation in liquid, applications to biology**		**AR**	
L27-AR	**Dec. 2**	**Special Topics III – multi-frequency methods, subsurface imaging**		**AR**	**Term project reports due**
	Dec. 7	**Student project presentations**			
	Dec. 9	**Student project presentations**			