MSE640: Advances in Investigation of Intermolecular & Surface Forces

Course Title	***Advances in investigation of Intermolecular & surface forces***
Course Code	MSE640
Credit Hours	3
Pre-requisites (if any)	MSE507, MSE508 or equivalent with permission of Instructor
Co-requisites (if any)	
Name of Faculty	Dr Matteo Chiesa
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Office hours of Faculty	TBA
Brief Course Description	Intermolecular forces embrace all forms of matter, and yet one finds very few university courses devoted to the fundamental aspects of this subject. This course aims at presenting a comprehensive view of intermolecular and surface forces and the common way to investigate these forces by means of different scanning probe microscopy techniques. The first part of the course will describe the role of such force in determining the properties of simple and complex system. This subject touches on a very broad area of phenomena in physics, chemical engineering and biology and due to the wide range topic covered and different disciplines to which the course is addressed, I have presumed only the basic knowledge of molecular science. The second part of the course present the fundamentals underlying Atomic Force Microscopy (AFM) for the investigation of intermolecular and surface forces. AFM is one of the foremost tools for imaging, measuring, and manipulating matter at the nanoscale by gathering information of the surface throughout a mechanical probe.
Course Objectives	The main objectives of the course are to: • Understand the foundations of intermolecular & surface forces and recognize their importance at the nanoscale. • Acquire a comprehensive and unified view of intermolecular and surface forces describing their role in determining the properties of simple and complex systems. • Acquire the ability to investigate of intermolecular and surface forces by means of different techniques of

	scanning probe microscopy and being able to interpret the results obtained from a physical point of view in a critical manner.
Program Outcome	Demonstrate appropriate depth and breadth of knowledge that is at the frontier of their disciplines
Program Outcome	Use skills of interdisciplinary scholarship and research to integrate multiple perspectives
Program Outcome	Work effectively in a multidisciplinary collaborative environment using highly developed cognitive and creative expert skills and intellectual independence.
Program Outcome	Understand and value diverse approaches to solving critical problems in research and to creating new knowledge judged by international standards.
Program Outcome	Communicate effectively, in written and oral forms, their research results and/or critique highly complex and diverse matters to diverse audiences.
Program Outcome	Use self-development for personal and professional improvement in their field and contribute to its future advancement.

LECTURE	TOPICS COVERED		
L1	Course Overview; Review of Quantum Tunneling; Introduction to ST	Binnig et al. [Appl. Phys. Lett. 1982 and Phys. Rev. Lett. 1982], Hansma & Tersoff (reader)	
L2	STM experimental considerations	Binnig et al. [Phys. Rev. Lett, 1983] (reader)	HW 1 assigned
L3	Advanced Topics in STM		
L4	From STM to AFM	Binnig, Quate, Gerber (reader)	
L5	Interaction forces-I	Binnig, Quate, Gerber (reader) Intermolecular & Surface	

LECTURE	TOPICS COVERED		
		Forces Jacob Israelachvili ch 3,4	
L6	Interaction forces- II	Binnig, Quate, Gerber (reader) Intermolecular & Surface Forces Jacob Israelachvili ch 4,5	
L5	Interaction forces-III	Intermolecular & Surface Forces Jacob Israelachvili ch 5,6	
	Interaction forces-IV	Intermolecular & Surface Forces Jacob Israelachvili ch 6,7	
L7	F-Z, F-d curves – I	Butt, Capella, Kappl (reader)	**HW1 due; HW2 assigned**
L8	F-Z, F-d curves - II	Butt, Capella, Kappl (reader)	
L9	F-Z, F-d curves – III Introduction to contact mode and friction force imaging	Butt, Capella, Kappl (reader)	
L10	Three important calibrations: Z-piezo, optical lever sensitivity, and cantilever stiffness	Butt, Capella, Kappl (reader)	**Submit draft of term project proposal**
L11	Experimental uncertainties in extracting elastic modulus or adhesion from F-Z curves	Butt, Capella, Kappl (reader)	
L12	Dynamic AFM methods	Garcia and Perez (reader)	**Submit final draft of term project proposal**
L13	Point mass oscillating models, linear vs. nonlinear oscillations		**HW2 due, HW 3 assigned**
L14	Dynamic Approach Curves	Garcia and Perez (reader)	
L15	Continuous beam models; cantilever eigenmodes	Garcia and Perez (reader)	

LECTURE	TOPICS COVERED		
L16	Measuring the true height of water films on surfaces	Santos et al. (reader from Nanotechnology and JPC C LENS)	
L 17	Multiple period orbitals and sub-harmonic excitation induced by water impacts at the nanoscale	Santos et al. (reader from JAP LENS)	
L 18	Analytical approaches – phase contrast, energy dissipation, imaging forces		**HW3 due, HW4 assigned**
L 19	Energy dissipation at the nanoscale	Garcia et al. S. Santos , et al. *Nanotechnology* (reader from Nanotechnology LENS)	
L 20	How localized are energy dissipation processes in nanoscale interactions	Santos et al. (reader from Nanotechnology LENS)	
L 21	Disentangling the physical origins of energy dissipation in the nanoscale	Santos et al. (reader from Journal of Physics D and Nanoscale LENS)	
L 22	Theory of frequency shifts		
L 23	Implementing FM-AFM	J. Font et al. (reader from Nanoscale LENS)	**HW4 due, HW5 assigned**
L 24	FM-AFM Results		
L 25	Special Topics I – Electrostatic Force Microscopy, Magnetic Force Microscopy	Asylum Research Notes K.R. Gadelrab et al. (reader from JMR LENS)	**HW 5 due**

LECTURE	TOPICS COVERED		
L 26	Special Topics II – Operation in liquid, applications to biology	Asylum Research Notes Daniel Kiracofe and Arvind Raman Nanotechnology 2011 S. Santos et al. (reader from JPC C LENS)	
L 27	Special Topics III – multi-frequency methods, subsurface imaging, PFM	Asylum Research Notes	
L28	Student project presentations		

Out-of-class assignments	See above
Course Grading	The overall grade will be determined as follows: Homework 35%; Individual project: 30% Final exam: 30% Attendance: 5%
Teaching and learning methodologies	Weekly Lectures and Tutorials
Main course texts	**Text:** There is really no required textbook for the course.
Recommended readings	A lot of the material is covered in the *course reader* – a selection of key review and historical articles: 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. A list of papers will also be provided
Instructional materials and resources	www.nanohub.org