Department of Mechanical Engineering
ME EN 5960/6960 Nano-Tribology and Contact Mechanics – Fall 2011

Syllabus

Instructor:	**Prof. Bart Raeymaekers**, MEB 2122, bart.raeymaekers@utah.edu Research website: http://mech.utah.edu/tribology
Office Hours:	Tue/Thu 12:05 – 12:35 pm, and by appointment
Units:	3
Meeting Times:	Tue/Thu 10:45 am – 12:05 pm, WEB 1460
Engineering Lab:	CADE Lab and Engman Lab
Recommended Text:	*Tribology on the Small Scale*, C. M. Mate Oxford University Press (2008), ISBN 978-0-19-852678-0 Extra readings and relevant research papers will be made available on the course website.
Reference Texts:	*Hydrodynamic Lubrication*, Y. Hori *Friction and Wear of Materials, 2nd edition*, E. Rabinowicz *Friction, Wear, Lubrication*, K.C. Ludema *Wear*, G. Stachowiak
Course Website:	Blackboard/WebCT
Pre-requisites:	**ME EN 3300, 3910, and Upper Division ME Status**

Course summary:

Nano-Tribology and Contact Mechanics is an advanced design course that focuses on friction, wear and lubrication, with an emphasis on the nanoscale. The course introduces traditional tribology and contact mechanics theory as well as hydrodynamic theory. Recent advances in nano-tribology research are discussed and highlighted. Applications are chosen from the field of computer mechanics (hard disk drives), micro-electromechanical systems and orthopedics to illustrate the theory.

Course objectives:

This course will provide the student with the tools and methods to understand and solve real world engineering problems that involve friction, wear and lubrication. Additionally, seminal contributions in the literature and current active research will be summarized and discussed. At the end of the course the student will be able to

1. understand traditional and advanced metrology and characterization techniques to visualize/image, describe, and analyze rough surfaces.
2. understand and apply classic tribology and contact mechanics theory to solve engineering problems that involve contacting rough surfaces on the nanoscale.
3. understand and apply techniques such as digital signal processing, and finite differences method to solve contact and lubrication (viscous flow) problems.

Course content:

Date	Topic	Detail	Reading
Tue 08/23	Introduction	Course administration + Chapter 1 in TB	Chapter 1 C.M. Mate
Thu 08/25	Introduction	Papers of Jost and Tysoe. Overview of tribology research	Papers: Jost/Tysoe
Tue 08/30	Characterizing surface roughness	Intro + examples, types of roughness, roughness parameters, distrubutions	Chapter 2 C.M. Mate
Thu 09/01	Characterizing surface roughness	McCool paper + measurement methods	Paper: McCool, Binnig
Tue 09/06	Tutorial on digital filtering in Matlab	Intro to digital signal processing/filtering + implementation in Matlab	Matlab HELP on DSP
Thu 09/08	Mechanical properties of solids and real area of contact	Atomic origins of deformation, types of contact, single asperity elastic model: Hertz theory	Chapter 3 C.M. Mate (up to 3.4)
Tue 09/13	Mechanical properties of solids and real area of contact	Multi asperity elastic models: Greenwood Williamson	Chapter 3 C.M. Mate + Paper: GW
Thu 09/15	Mechanical properties of solids and real area of contact	Plasticity index + Equivalent rough surface + multi asperity elastic /plastic models: Chang Etsion Bogy	Paper: Greenwood Tripp/CEB
Tue 09/20	Friction	Amonton's law and Coulomb friction, adhesive friction theory (Bowden and Tabor)	Chapter 4 C.M. Mate (up to 4.3)
Thu 09/22	Friction	Static friction and stick slip	Chapter 4 C.M. Mate (4.4)
Tue 09/27	Friction	Overview of research on static contact mechanics	Selected papers
Thu 09/29	Surface energy	Interfacial energy, work of adhesion, surface energy of solids, contact angle measurements	Chapter 5 C.M. Mate
Tue 10/04	Surface forces derived from surface energies	Derjaguin approximation, dry environment sphere on flat, adhesion induced deformation	Chapter 6 C.M. Mate (up to 6.3)
Thu 10/06	Midterm		
Tue 10/11	Fall Break		
Thu 10/13	Fall Break		
Tue 10/18	Surface forces derived from surface energies	JKR and DMT model	Papers: JKR/DMT
Thu 10/20	Surface forces derived from surface energies	Wet environment sphere on flat, Van Der Waals forces	Chapter 6 C.M. Mate (6.3)
Tue 10/25	IJTC Meeting Los Angeles		
Thu 10/27	Measuring surface forces	AFM and surface force apparatus	Chapter 8 C.M. Mate
Tue 11/01	Lubrication	Stribeck curve, lubrication regimes + examples, Newtonian and non-Newtonian viscosity, intro to Reynolds equation	Chapter 9 C.M. Mate
Thu 11/03	Hydrodynamic lubrication	Reynolds equation, compressible versus incompressible Reynolds equation	Chapter 2, 4 Y. Hori
Tue 11/08	Hydrodynamic lubrication	Plane slider bearing, Rayleigh step bearing	Chapter 9 C.M. Mate Paper: Lacey, Talke
Thu 11/10	Hydrodynamic lubrication	Squeeze film lubrication	Chapter 7 Y. Hori
Tue 11/15	Laser surface texturing	Process overview, benefits, applicability	Papers: Etsion, Raeymaekers
Thu 11/17	Wear	Archard wear equation, wear coefficient, wear maps, wear mechanisms	Chapter 12 C.M. Mate
Tue 11/22	Wear	Overview of research on wear, real world applications	Selected papers
Thu 11/24	Thanksgiving Break		
Tue 11/29	Advanced topics	Fretting wear	
Thu 12/01	Project presentations	Project presentations	
Tue 12/06	Project presentations	Project presentations	
Thu 12/08	Exam review		

Deliverables:

Homework	30%
Midterm	20%
Project	30%
Final exam	20%

Midterm: Thu 10/08/11 – in class
Final: Thu 12/16/11 – 10:30 am - 12:30 pm

- Homework is due before the start of the lecture. Late HW will be accepted until 5 pm on the due date, but the grade will be discounted by 20%.
- Each student will be assigned an individual term project. Term papers are due on Tue 11/29 before class.
- All exams are "closed book". Midterm material will be specified timely. Final exam will be comprehensive.
- The final grade will be "curved".
    - A: The student shows outstanding understanding of the course material.
    - B: The student shows good understanding of the course material.
    - C: The student shows adequate understanding of the course material.
    - D: The student shows poor understanding of the course material.

Academic dishonesty policy: ME EN 5960/6960 will strictly follow the standard academic policy outlined by the University and the College of Engineering.

Faculty and student responsibilities:

No laptops, cellular/smart phones are allowed during class meeting times.

All students are expected to maintain professional behavior in the classroom setting, according to the Student Code, spelled out in the Student Handbook. Students have specific rights in the classroom as detailed in Article III of the Code. The Code also specifies proscribed conduct (Article XI) that involves cheating on tests, plagiarism, and/or collusion, as well as fraud, theft, etc. Students should read the Code carefully and know they are responsible for the content. According to Faculty Rules and Regulations, it is the faculty responsibility to enforce responsible classroom behaviors, beginning with verbal warnings and progressing to dismissal from class and a failing grade. Students have the right to appeal such action to the Student Behavior Committee.

"Faculty…must strive in the classroom to maintain a climate conducive to thinking and learning." PPM 8-12.3, B.

"Students have a right to support and assistance from the University in maintaining a climate conducive to thinking and learning." PPM 8-10, II. A.

ADA statement: "The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Union Building, 581-5020 (V/TDD). CDS will work with you and the instructor to make arrangements for accommodations." (www.hr.utah.edu/oeo/ada/guide/faculty/)