MIE 1744 – Nanomechanics of Materials

Department of Mechanical & Industrial Engineering

School of Graduate Studies, University of Toronto

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1. **Lectures:** Schedule TBD

2. **Marking Scheme:**

Final Project Report (Due: TBD)	100%

3. **References:**

<u>Recommended Textbooks and References:</u>

A.N. Cleland. *Foundations of Nanomechanics*, Springer (2003) ISBN: 3-540-43661-8

E. Gnecco & E. Meyer. *Fundamentals of Friction and Wear on the Nanoscale,* Springer (2015) ISBN: 978-3319105598

4. **Course Description:**

Materials can exhibit dramatically altered mechanical properties and physical mechanisms when they have characteristic dimensions that are confined to small length-scales of typically below ~ 100 nm. These size-scale effects in mechanics result from the enhanced role of surfaces and interfaces, defects and material variations, and quantum effects. Nanostructured materials which exhibit these size-scale effects often have extraordinary mechanical properties as compared to their macroscopic counterparts. This course is designed to provide an introduction to nanomechanics and size-scale mechanical phenomena exhibited by nanostructured materials, and provide a platform for future advanced studies in the areas of computational/experimental nanomechanics and nanostructured materials design and application. Topics include: an introduction to nanomechanics; atomic/molecular structure of materials & nanomaterials synthesis; limitations of continuum mechanics, nanomechanical testing techniques (AFM, nanoindentation, in situ SEM/TEM); atomistic modeling techniques (DFT, MD, Course-grained MD); size-scale strength, plasticity, and fracture **;** Hall-Petch strengthening, superplasticity; nanotribology**,** atomistic origins of friction, nanoscale wear; nano-bio-mechanics; mechanics of nanocomposites.

5. **Major Course Sections:**

1. *Introduction to Nanomechanics* (Lecture 1)

2. *Atomic/molecular structure of materials & nanostructure synthesis* (Lectures 2-3)

   - Review of crystal structure, defects, and dislocations
   - Polymer molecular structure
   - Top down & bottom up synthesis approaches
   - 1D nanomaterials (nanowires & nanotubes)
   - 2D nanomaterials (atomically thin films)
   - 3D nanomaterials (nanograined materials & nanocomposites)

3. *Limitations of continuum mechanics* (Lecture 4)

   - Intra- and intermolecular forces
   - Surface energy and adhesion forces
   - Contact mechanics models and assumptions

4. *Nanomechanical testing techniques* (Lectures 5-6)

   - Atomic Force Microscopy & Friction Force Microscopy
   - Nanoindentation
   - MEMS testing devices
   - In-situ SEM/TEM testing

5. *Atomistic modeling techniques* (Lecture 7)

   - Density Functional theory
   - Molecular Dynamics simulations
   - Course-grained MD simulations

6. *Size-scale strength, plasticity, and fracture* (Lectures 8-9)

   - Hall-Petch strengthening
   - Superplasticity
   - Multiscale fracture modeling

7. *Nanotribology* (Lecture 10)

   - Atomistic origins of friction
   - Single asperity vs multiple asperity contacts
   - Nanoscale wear
   - 3rd body layer

8. *Nano-bio-mechanics & Nanocomposites* (Lectures 11-12)

   - Liquids and wet environments
   - Single cell mechanics
   - Protein unfolding
   - Mechanics of bone and cartilage
   - Interfacial matrix-filler properties