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:**

   **Recommended Textbooks and References:**


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 (nanograinned 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