MAT505 Mechanical Behavior of Materials
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Office: FENS G046
Office Hours: N/A yet (Feel free to stop by as long as I am available)

Course description: This course is intended to bridge the introductory materials science knowledge to mechanical behavior of various crystalline and amorphous systems. It covers the influence of microstructure on the mechanical behavior of materials including metallic alloys, polymers and ceramics. The main objective of the course is to explain the fundamentals laws of elasticity followed by plastic behavior and deformation. In the meantime, the ways in which microstructure and defects are exploited to fabricate high-performance materials that are applied to today's technologies ranging from aerospace to toughened ceramics will be described. The content includes and is not limited to stress-strain relations, elastic and plastic deformation, dislocations, dislocation interactions, work hardening, vacancies, interaction of precipitates with defects, glass transition in polymers, creep in materials, brittle fracture and ductile fracture, viscoelastic behavior and case studies that span a wide variety of phenomena including fatigue in alloys.

The outline of the course can be summarized under the following titles:

1. Stress, strain and deformation (2-3 weeks)

Definition of stress and strain, engineering and true stress/strain
Stress-strain curves
Generalized Hooke's law, relations in elasticity, tensor representations
Principal and shear stresses on an arbitrary plane, Mohr's circle

2. Line and planar defects in crystalline inorganic materials and plastic deformation (2 weeks)

A general overview on commonly observed defects in crystalline solids
Stress-strain curves: The plastic part in alloys
Dislocation types and their characteristics
Slip and shear
Interaction of grain boundaries with dislocations
Dislocation reactions

3. Basic strengthening mechanisms of alloys (1-2 weeks)

Phase transformations: Why do we need them?
Solid solutions, ordering and precipitates
Conditions for stabilization of a desired precipitate in a matrix
Work hardening
Grain-boundary strengthening
Precipitation hardening, solid solution hardening
Dispersion hardening
Comparison of ferrous alloy strengthening vs. non-ferrous alloys

4. Fracture: Brittle fracture and ductile fracture (2 weeks)

Formation of a crack in a crystal
Fracture of metals and alloys
Fracture of ceramics
Modes of fracture
Failure types of alloys
Failure of polymer materials

5. Creep and high temperature deformation (1-2 weeks)

Vacancies at high temperatures and dislocation activation energy.
Diffusion of vacancies under stress
Polycrystalline creep vs. single crystal creep
Creep embrittlement
Dynamic annealing
Creep resistant alloy design

6. Time dependent behavior, viscoelasticity (1-2 weeks)

Maxwell model, Kelvin-Voigt model, standard linear solid model and combinations thereof to represent time dependent deformation of materials, specifically polymers. A basic introduction to the Laplace transform is given to solve problems. Dynamical Mechanical Analysis is discussed in relation to the viscoelastic material parameters.

7. Some special materials, materials selection and case studies (depending on available time)

Reference Books (at the moment):

- **Mechanical Metallurgy, George E. Dieter.**
- **Mechanical Behavior of Materials, Thomas H. Courtney.**
- Physical Metallurgy Principles, Hill and Abbaschian
- Phase Transformations in Metals and Alloys, Porter and Easterling
- Principles of Polymer Engineering, McCrum, Buckley, Bucknall

A number of documents from online resources and compiled by the lecturer will be shared with the class.