ENS 205 Introduction to Materials Science (Fall 20-21)

Intended Audience:
An introductory undergraduate level course for all interested FENS students especially for MAT, BIO, ME, and IE programs.

Scope:
To provide fundamentals of how interactions and structure at atomic scale lead to macroscopic properties and to introduce the fundamental thermodynamic/kinetic concepts operating on the structure for the design and implementation of materials with novel functions. The class will also give insight to what MAT Engineers do in industry.

Schedule:
Week 1 / 3 hours
General concepts and definitions
Understanding interactions in materials at the atomic scale
Functional Materials, How to make functional materials
Why nanomaterials are important
Broader / Social Impact of Materials Science
Atomic bonding, Crystals, Classification of crystals

Week 2 / 3 hours
Engineering Materials
Crystals, Bonding, Failures, Primary bonding
Symmetry
Lattice positions, directions and planes; fundamentals of x-ray diffraction

Week 3 / 3 hours
Secondary bonding (Hydrogen bonds, Van der Waals bond)
Electronegativity, Polar crystals
Lattice, Unit cell, Atomic packaging factors
Arrangement of particles inside crystals

Week 4 / 3 hours
Lattice positions, directions, and planes; fundamentals of x-ray diffraction
Miller indices

Week 5 / 3 hours
Defects, Dislocations
Diffusion, Thermal activation of processes; time-dependent changes
Arrhenius plot, Activation energy, Fick's Law

Week 6 / 3 hours
Mechanical properties of materials
The response of materials to mechanical changes: Stress-strain curves, Tensile test
Elastic and plastic deformation; measurements by creep and stress relaxation

Week 7 / 3 hours
Thermal properties of materials
The response of materials to heat: Heat capacity, thermal expansion, thermal conductivity
Debye Model, Dulong-Petit
Failure analysis and Prevention, Ductile-to-Brittle transition, Experiments; failure analysis

Week 8 / 3 hours
Phase diagrams
The lever rule, stability. Eutectic diagrams.
Development of microstructure during slow cooling

Week 9 / 3 hours
Kinetics, Heat treatment
Time-dependent phase transformations, Transformation on a temperature-versus-time plot (TTT diagram)
Nucleation
Development of microstructure during slow cooling
Ferrous and non-ferrous materials
Types of steel (stainless, cast, low carbon, mild etc)

Week 10 / 3 hours
Structural properties of polymers
Thermoset and thermoplastic materials
Additives, Metal Matrix Composites
Electrical properties of materials
Week 11 / 3 hours
Charge carriers, Hund rules
Energy levels, Doping in semiconductors
Electronic properties of Engineering materials
Optical and magnetic properties

Week 12 / 3 hours
Applications in Materials Engineering