ENGR 240 Final Exam Review Sheet

NOTE: You will be given all formulas necessary for the exam, but you must know what the variables in the formulas represent as well as how and when to use the formulas.

Introduction

- Very basic description & typical properties of polymers, metals, ceramics, semiconductors, and composites

Atomic Structure and Bonding

- Force vs. interatomic separation plot
- Energy vs. interatomic separation plot
- Relationship between bonding force and bonding energy (energy is the integral of Fdr)
- Stiff versus flexible material – effect on the shape of the "energy well" (E vs. r plot)
- Effect of "energy well" shape on thermal expansion
- Primary interatomic bonds
  - Ionic, covalent, metallic – basic description of each type
  - Equation for percent ionic character
- Secondary interatomic bonds – Van der Waals, hydrogen

Crystallography & Structure of Solids

- Difference between crystalline and amorphous
- Meaning of lattice, crystal structure, unit cell, lattice parameters (angles and edge lengths)
- Crystal geometry
  - Crystallographic direction indices
  - Crystallographic planes (Miller indices)
- Crystal structures
  - Simple cubic, face centered cubic, body centered cubic, hexagonal close packed – be very familiar with these (know position of atoms)
  - Ceramic structures – positive and negative ions; you may have to identify the number of atoms per unit cell in a ceramic crystal structure
- Atomic packing & density calculations
  - APF
  - Planar atomic density
  - Linear atomic density
- Polymorphs of compounds and allotropes of pure elements
- Single crystals, polycrystalline solids, and noncrystalline solids
- Specific volume vs. temperature plot for amorphous versus crystalline solids

Imperfections in Solids (Callister Chapter 4)

- Types of defects
- Point defects:

Vacancies
Self-interstitials
Impurities – substitutional and interstitial
Number of vacant sites in a solid (equation)
Temperature effects on vacancy concentration
Factors that determine extent of solid-state solubility (Hume-Rothery rules)

- Line defects:
  Edge dislocations
  Strain fields around an edge dislocation
- Planar defects:
  External surfaces, grain boundaries
- Volume defects
  Cracks, pores, inclusions

Diffusion (Callister Chapter 5)

- Interdiffusion (impurity diffusion)
- Vacancy and interstitial diffusion mechanisms
- Fick's first law – steady state diffusion
- Diffusivity equation
- Effects of activation energy and temperature on diffusivity
- Effects of structure packing and size of diffusing species on diffusion coefficients
- Fick's second law – nonsteady state diffusion (concentration gradients change with time)
- Diffusion paths – bulk (volume) diffusion vs. diffusion along grain boundaries

Electrical Properties (Chapter 19, Sections 19.1-19.12, 19.15)

- Ohm's law, resistivity, and conductivity
- 4-probe resistivity/conductivity measurements
- Material classification by electrical conductivity: insulators, semiconductors, conductors
- Energy band structures – individual atom energies vs. energy bands of solids
- Schematic band structures of conductors, semiconductors, and insulators
- Electron mobility
- Factors that affect electron mobility in metals
- Ionic conduction
- Intrinsic and extrinsic semiconductors; doping of silicon
- Effect of impurities (dopants) on the conductivity of semiconductors
- Semiconductors – temperature dependence of conductivity in intrinsic and extrinsic semiconductors

Phase Diagrams and Phase Equilibria (Callister Chapter 9)

- Fundamentals & definitions: component, phase, system, phase equilibria
- Two component systems – tie line and lever rule concepts
- Solubility limit, solvus line, liquidus line, solvus line
- Hypoeutectic, hypereutectic, eutectic compositions (and hypoeutect*oid*, etc.)
- Solidification in binary systems – binary isomorphous and binary eutectic

- Solidification structures – phases and microconstituents
- Microstructures – be able to identify phases and microconstituents in binary eutectic systems (and sketch schematic microstructures)
- Phase diagram labeling – two-phase regions and 3-phase equilibria

Mechanical Properties (Callister Chapter 6)

- Engineering stress and strain
- Modulus of elasticity (Young's modulus)
- Ductility – %EL and %RA
- Tensile & yield strengths
- Types of yielding – gradual and well-defined
- Types of deformation – elastic, uniform plastic, nonuniform plastic (necking)
- Toughness
- Strain Hardening
- Hardness – types of hardness tests

Dislocations and Strengthening Mechanisms (Callister Chapter 7, Sections 11.7-11.8)

- Dislocation density
- Dislocation motion (slip)
- Dislocation interactions with other defects
- Strain fields around edge dislocations
- Slip, slip systems, slip planes and slip directions
- Slip in different crystal systems – FCC compared to BCC, HCP, BCT
- Strengthening mechanisms – be familiar with strain hardening, solid solution strengthening, grain boundary strengthening, precipitation hardening
- Cold work and recrystallization – microstructural changes & property changes as a function of annealing time & temperature
- Recrystallization temperature – effects of prior cold work, alloying elements, and the material's absolute melting temperature on the recrystallization temperature
- Precipitation hardening – properties as a function of aging time, effect of precipitate spacing, overaging

Fracture and Failure (Callister Chapter 8)

- Brittle and ductile fracture
- Stress concentration and fracture toughness
- Critical stress compared to yield strength
- Impact strength – impact energy; fcc vs. bcc, hcp structures
- Fatigue – S-N curves, fatigue limit, fatigue strength
- Creep failure – creep rate, temperature effects in creep, creep damage, improvement of creep resistance

Phase Transformations and Microstructures (including the steel stuff)

- Nucleation and growth in a phase transformation
- Nucleation rate, growth rate, and overall transformation rate as a function of temperature
- Effects of transformation temperature on microstructure and properties (coarse versus fine structures with liquid to solid and solid to solid transformations)
- Transformation microstructures in the Fe-Fe_3C system (austenite to pearlite, ferrite, bainite, martensite)
- Steel microstructures (appearance, phases, and properties): pearlite, bainite, martensite, proeutectoid ferrite, austenite
- Use of TTT diagrams to determine microstructures in isothermally transformed steel
- Martensite formation in steel (diffusionless austenite to martensite change, structure change upon quenching, etc.)
- Properties of martensite
- Tempering of martensite (basic microstructural changes and effect on properties
- Hardenability in steel – effect of C and other alloying elements on the hardenability of steel
- Other metal alloys (handout) – basic advantages and disadvantages

Polymers (Callister Chapters 15 and 16)

- Polymer structure and bonding
- Thermoplastics and thermosets
- Polymer structure – linear, branched, crosslinked
- Polymer crystallinity – factors that affect the degree of crystallinity, polymer crystals
- Effects of crystallinity on properties
- Glass transition – behavior of polymers above and below T_g
- Factors that affect the glass transition temperature
- Stress-strain behavior of polymers – brittle, plastic, and elastomeric
- Influence of temperature on properties, e.g., stress-strain behavior

Ceramics

- Basic structure – positive and negative ions, ionic and covalent bonding
- Layered structures – silicates (clays) and graphite
- Ceramics (crystalline) versus glasses (amorphous)
- General properties (thermal, mechanical, electrical)
- Effect of defects on mechanical properties

Composites

- Advantages of composites over other materials
- Matrix properties versus fiber properties
- Fiber reinforced plastics – roles of matrix and fibers
- Effects of fiber orientation on properties