

Final Review

Chapter 2: Bonding

2.1 – Introduction (pg. 11)

- Electrostatic attraction: reason why atoms bond together.
- Cohesive energy: energy released when atoms combine.
- Bond Model focuses on interaction between valence electrons/Band model focuses on molecular orbital

2.2 – Electron Configurations in Atoms (pg. 12)

- The orbital goes $1s^2 2s^2 2p^6 3s^2 3p^6 \dots$

2.2.2 – The Iron Core and the Valence Electrons (pg. 14)

- Valence electrons are the sum of the outermost s and p orbitals

2.3 – The Bond Model (pg. 15)

2.3.1 - Bonding as an Electrostatic Interaction (pg. 15)

2.3.2 – The Three mechanisms of Chemical Bonding (pg. 16)

- Covalent/Metallic, Ionic bonds, Dipole moment

2.3.3 – Shared Valence Electrons: Covalent and Metallic Bonding (pg. 17)

- Covalent Bonding: Electrons are shared – bonds are saturated – Used in molecular solids, semiconducting solids and elemental insulators – Poor conductors (pg. 18) – Bonds are directional
- Metallic Bonding: Unsaturated bonds – Sea of electrons – High electrical conductivity – Non directional – Ductile

2.3.4 – Ionic Bonding (pg. 19)

- Electrons are transferred from one atom to atom – Usually an insulator – Degree of ionicity related to difference in electro-negativity.

2.3.5 – Dipole Bonding (pg. 20)

- No charge transfer – Inhomogeneous charge distribution – Dangling Hydrogen atoms – Electrical insulators
- Vanderwalls Bond: Due to transient dipole moments – Very weak attraction

2.4 – Band Model (pg. 22)

2.4.1 – Electron energy levels in atoms (pg. 22)

2.4.2 – Electron energy levels in solids (pg. 23)

2.4.3 – Core States and Valence Bands in Solids (pg. 25)

2.4.4 – The Band Model of Conductor Type (pg. 27)

- Band Structure for Metallic conductor: The valence band is half filled (monovalent), the valence and conduction bands overlap (divalent), partially filled d-band (transition).
- Odd number of valence = metallic
- Band structure of Semiconductor/ Insulator: $E_G > 2\text{eV}$ means insulator, $E_G < 2\text{eV}$ means semiconductor.

Chapter 3: Crystal Structure

3.1 – The Concept of Microstructure (pg. 30)

- Crystalline solid: Periodic repetition, ordered
- Amorphous solids: random distribution (Eg. Glasses)

3.2 – Crystals In two Dimensions (pg. 31)

3.2.1 – The Crystal Lattice (pg. 32)

- Primitive Cell: One atom or lattice point per cell
- Crystal Lattice: Periodic distribution of points in space
- Crystal Structure: Atom Distribution – $\mathbf{r}_i = m\mathbf{a}_1 + n\mathbf{a}_2 + t\mathbf{a}_3$

3.2.3 – The Two Dimensional “Bravais” Lattice (pg. 34)

3.2.4 – Basis Vectors in Bravais Lattices (pg. 37)

- Simple hexagonal Structure
- 3.3 – Crystals in 3 Dimensions (pg.38)
 - 3.3.1 – Three Dimensional Crystals Lattices(pg. 38)
 - This section explains how to define the primitive cell in space
 - 3.3.2 – The Bravais Lattice (pg. 39)
 - Talks about the Bravais lattice classes

- 3.4 – Points Directions and Planes in a crystal (pg. 44)
 - 3.4.1 – Points in a Crystal (pg.44)
 - $(h,k,l) \Rightarrow$ points, $\{h,k,l\} \Rightarrow$ family of points
 - 3.4.2 – Directions in a Crystal (pg. 45)
 - $[hkl] \Rightarrow$ vectors, $\langle hkl \rangle \Rightarrow$ family of vectors
 - 3.4.3 – Planes in a Crystal (pg. 47)
 - $(hkl) \Rightarrow$ planes, $\{hkl\} \Rightarrow$ family of planes
 - Take reciprocals of plane (abc) to get the miller indices of plane
 - The plane (hkl) is perpendicular to the direction $[hkl]$
- 3.5 – The Common Crystal Structures (pg. 49)

	Substitutional	Interstitial
BCC	CsCl	Nb ₃ Sn
FCC	Cu ₃ Au	NaCl, beta-Zns
HCP		alpha - ZnS

- Substitutional Compounds: Substituting atoms on the sites of the structure
- Interstitial Compounds: Placing atoms in the voids
- 3.6 – The Close-Packed Structures: FCC and HCP (pg. 49)
 - 3.6.1 – The FCC and HCP structures (pg. 49)
 - FCC: 4 atoms/unit cell – 1 atom /lattice point – 4 lattice point/ cube
 - HCP: 6 atoms/ unit cell – 2 atoms/ lattice point
 - 3.6.3 – Interstitial sites in the FCC and HCP Structures (pg. 53)
 - FCC: 4 octahedral voids/8 tetrahedral voids
 - 2 tetrahedral voids/atom – 1 octahedral void/ atom
 - 3.6.4 – Properties of materials with the FCC and HCP Structures (pg. 55)
 - FCC and HCP are usually metals since each atom has 12 neighbors and cannot form saturated bonds.
 - They are malleable and easily deformed
 - HCP is very directional and therefore is not used in engineering.

- 3.7 – The Body-Centered Cubic Structure (pg. 55)
 - 3.7.1 – The BCC Unit Cell (pg. 55)
 - 2 atoms/ unit cell – 2 lattice points/cube – 8 nearest neighbors
 - These form metallic conductors because no saturated bonds can be formed.
 - 3.7.2 – Interstitial Voids in the BCC Structure (pg. 56)
 - Voids are distorted and asymmetric
 - 6 octahedral voids/ unit cell or 3/atom – 12 tetrahedral voids/unit cell r 6 per atom

- 3.8 – The Diamond Cubic Structure (pg. 58)
 - 3.1.8 – The Diamond Cubic Cell (pg. 58)
 - Ordered Interstitial Structure – Atom positions do not form a Bravais lattice
 - 3.8.2 – The DC Structure as a Stacking of Planes and Interstitials (pg. 59)
 - Carbon type materials – Small electrical conductivity because of large band gap – Hard and brittle

- 3.9 – Solid Solutions and Compounds (pg. 60)
 - 3.9.1 – Solid Solutions (pg. 60)
 - Substitutional Solutes: Large and similar in chemical character atoms will replace solvent atoms in the crystal lattice.
 - Interstitial Solutes: Small atoms that have different chemical character will occupy empty spaces in the lattice.
 - Alloys are random fillings - compounds are ordered filling

- 3.9.2 – Random Solutions; pseudo-atoms (pg. 60)
- 3.9.3 – Ordered Solutions (Compounds) (pg. 61)
 - Decrease in temperature can convert disordered to ordered compounds.
 - The Bravais lattice of a ordered compound will have different symmetry than the parent structure
- 3.10 – Substitutional Compounds (pg. 63)
 - 3.10.1 – Substitutional BCC Superstructure: CsCl
 - Center and corner atoms are entirely equivalent.
 - Metallic or ionic bonds and non saturated bonds.
 - Example of cool down process to reorder the atoms (pg. 64)
 - 3.10.2 – Substitutional FCC Superstructure: Cu₃Au (pg. 64)
 - Metallic bonds. Used to make superconductors
- 3.11 – Interstitial Compounds (pg. 65)
 - 3.11.1 – Octahedral Interstices in FCC: NaCl (pg. 65)
 - Na placed at all FCC locations while Cl goes into all the octahedral voids
 - Equivalent ionic bonds – no saturated bonds – can be metallic
 - 3.11.2 – Tetrahedral interstices in FCC: beta-ZnS (pg. 66)
 - Zn at FCC lattice sites and S in the tetrahedral voids – 4 equidistant neighbors – AaBbCc stacking
 - Covalent bonds, sometime ionic
 - 3.11.3 – Tetrahedral Interstices in HCP: alpha-ZnS (pg. 67)
 - Insulators because lower energy when the species are ions. Large band gaps.
 - 3.11.4 – Tetrahedral Interstices in BCC: Nb₃Sn (pg. 67)
 - Two of the voids on each face are occupied
 - Superconductors. The separated chains of tetrahedral atoms provide conductivity
- 3.12 – (pg. 68)
 - 3.12.2 – The Structures of Solid Solutions (pg. 72)
 - 3.12.3 – The structures of Ordered Compounds (pg. 73)
 - Substitutional compounds: Formed by elements similar in size and electro negativity.
 - pg. 73 explains why CuAu forms FCC solids at all compositions
 - Interstitial Compounds: Ionic compounds and inter-metallic compounds (pg. 74)

Chapter 4: Defects in Crystals

- 4.1 – Introduction (pg. 76)
- 4.2 – Point Defects (pg. 77)
 - Intrinsic defect which occur in pure materials
 - Extrinsic defects which occur in solute or impurity atoms.
 - 4.2.1 – Intrinsic defects (pg. 76)
 - These defects are vacancies (common) created by a missing atom or atom occupies interstitial site where no atom should be found called interstitially(uncommon, high energy)
 - Explains Schottky defect, Frenkel defect and anti-site defect.
 - 4.2.2 – Extrinsic Defects (pg. 78)
 - Foreign atoms called solutes or impurities. Large atoms are Substitutional solutes and small atoms are interstitial solutes.
 - Donors and acceptors in semiconductors (pg. 78) explains why adding boron to silicon can make silicon conductive. These semiconductors are extrinsic.
 - Solution Hardening: Adding a solute almost always makes the material stronger(pg. 79 explains why). Examines why steels and alloys are very strong. BCC will harden better because of non-symmetric voids.
 - Tetragonal distortion by octahedral interstitials in BCC. (pg. 81 explains change from BCC to BCT)
- 4.3 – Line Defects: Dislocations (pg. 82)
 - These act as electrical defects in semiconductors
 - 4.3.1 – The Edge Dislocation (pg. 82)
 - Burger vector is perpendicular to the dislocation line
 - Plastic deformation changes the shape of the body without changing the volume.
 - 4.3.2 – An Edge Dislocation in a Simple Cubic Crystal (pg. 85)
 - 4.3.3 – The Burgers Circuit (pg. 87)
 - Start finish technique explained on that page
 - 4.3.4 – Motion of an Edge Dislocation: Climb and Glide (pg. 87)

- Glide require less energy then climb
- Glide can only go in one direction
- Climb requires the elimination of atoms by vacancies when going up and addition of vacancies when going down. Easier at high temperatures because concentration of vacancies is high.
- 4.3.5 – Screw Dislocations (pg. 89)
 - When the burger vector is parallel to the dislocation line
- 4.3.6 – Screw Dislocations and Plastic Deformations (pg. 91)
 - Screw dislocation is very similar to edge dislocation except that the screw does not pass the entire width of the body
- 4.4 – Two-Dimensional Defects: Interfaces (pg. 95)
 - 4.4.1 – Free Surfaces (pg. 95)
 - 4.4.1 – Interfaces Between Crystals (pg. 98)
 - Low-angle tilt boundary, low angle twist boundary, high angle boundary
 - Coherency: If it is possible to order the phases on both sides of the interface. You can lose coherency with accumulation of dislocations at the interface.
 - 4.3.3 – Interfaces within Crystals (pg. 103)
 - Stacking fault: Defect in a sequence of atom distributions (extrinsic, intrinsic, twin)
 - Anti-phase boundary: Defect in a sequence of atom distributions over the planes. Only in ordered compounds
- 4.5 – Volume Defects (pg. 105)
 - Precipitates, dispersants, inclusions, voids

Chapter 5: Glasses

- 5.1 - Introduction (pg. 107)
- 5.2 – The Glassy State (pg. 107)
 - Obtained by quenching. The more complicated the geometry of the structure the easier it is to glassify.
 - Configurational Glasses: Long chain polymers whose long chains make crystallization difficult.
 - Chemical Glasses: Solutions or compounds whose local bonding inhibits crystallization
- 5.3 – Configuration Glasses (pg. 108)
 - This page has a graph explaining what happens when slowly quenching and fast quenching and glass promoting circumstances
 - Most glasses are thermoplastic, easy to deform and shape at high temperatures.
- 5.4 – Chemical Glasses (pg. 110)
 - 5.4.1 – Network Oxides (Quartz) (pg. 110)
 - Promoted by glass forming additives like other oxides and ionic species
 - The additives disrupt the the pattern of silicate tetrahedral and must be rejected to form the quartz crystal. Quenching the material trap in the solid and prevent crystallization.
 - Silica is thermoplastic easy to heat up and shape since it acts as a viscous liquid.
 - 5.4.2 – Cross-linked polymers (pg. 112)
 - Explains why these form glasses easily
 - They are thermosetting

Chapter 6: Macromolecular Solids

- 6.1 – Introduction (pg. 114)
- 6.2 – Polymers (pg. 114)
 - Almost always carbon-carbon bonds. Polymer is a molecule that is made by repetition.
 - Chain polymers: Linear molecules that that are joined by polar bonds
 - Network Polymers: Individual molecules are joined together by molecular bonds to create networks
- 6.3 – Chain polymers (pg.115)
 - 6.3.1 – Types of Chain Polymers (pg. 115)
 - Must be able to bond to replicas of itself at both ends. Provide Unsaturated bonds at both ends
 - Addition Polymers: Unsaturated carbon bonds, double bonds between carbon atoms, sequential addition to the sides
 - Condensation Polymers: Does not contain a double bond in its central chain and therefore cannot add copies if itself (pg. 116)
 - 6.3.2 – Internal Symmetry in Chain Polymers (pg. 117)

- Asymmetric Monomers: different molecular side groups are bonded to the two sides of a carbon atom. Isotactic if R group always on the same side. Syndotactic if R group alternates. Atactic if it is random. The first two are easy to crystallize because more regular than the last one.
 - Cis configuration is good for elastomers while trans is straight (pg. 118)
 - 6.3.4 – Solid Aggregates of Chain Polymers (pg. 120)
 - Fringed Micelle, Folded Chain, Spherulites, Plasticizers
 - Thermoplastic: It goes between solid and gas in a nearly continuous transition. Can be easily reshaped and formed.
 - Thermoplastic: Crystalline solids that melt and heat up discontinuously. They are strong but hard to shape.
 - 6.4 – Network Polymers (pg. 121)
 - They cannot move easily with respect to one another even at high temperature. Thermosetting
 - 6.4.1 – Network Polymers due to Multi-dimensional Bonds (pg. 122)
 - 6.4.2 – Network Polymers Due to Cross-links (pg. 122)
 - Explains how to make a network polymer.
 - 6.4.3 – Elastomers (pg. 123)
 - Full description at beginning of paragraph
 - Vulcanized rubber (cis configuration), the C=C bonds cause the polymer chain to bend and kink. Coiled Springs.
 - 6.5 – Silicates (pg. 124)
 - Useful for insulators, dielectrics and structural materials. Stable at very high temperatures.
 - 6.5.1 – The SiO₄ tetrahedron (pg. 124)
 - Two ways to complete the O valence (valence 6 and not completely satisfied) explained pg. 125 in the picture.
 - 6.5.2 – Three Dimensional Network Structures (pg. 125)
 - Picture of Quartz. It is silica glass. Glass formation is promoted by the addition of solutes. Thermoplastic
 - 6.5.3 – Two Dimensional Sheet Structures (pg. 126)
 - Pictures of Mica, sheet plus plane pics.
 - 6.5.4 – One Dimensional Chain Structures.
 - Asbestos pictures.
- Chapter 7: ThermoDynamics**
- 7.1 – Introduction (pg. 138)
- 7.2 – Entropy (pg. 139)
- 7.2.1- Entropy and Time (pg. 139)
 - Entropy is the thermodynamic measure of time.
- 7.2.2. – Entropy and Heat (pg. 141)
 - Equation for dE pg. 142
- 7.2.3 – Entropy and Randomness (pg. 143)
 - Degeneracy: Number of ways something can be ordered.
 - Statistical entropy can only increase because combining two systems will create new states and the degeneracy will increase.
 - Electronic entropy, vibrational entropy, configurational entropy (pg. 145)
- 7.3 – The Conditions of Equilibrium (pg. 146)
- 7.3.1 – The Equilibrium of an Isolated System (pg. 146)
 - Entropy graph dS (pg. 147)
- 7.3.2 – Internal Equilibrium (pg. 148)
 - Thermal, Mechanical and chemical equilibrium derivations.
- 7.3.3 – Non equilibrium state: Constrained Equilibrium (pg. 150)
 - This section explains how materials are not in an equilibrium state but in a state that is continually trying to reach equilibrium. We can assume everything is an equilibrium because the rate of solute diffusion is extremely slow.
- 7.4 – Thermodynamic Potentials (pg. 152)
- 7.4.1 – Helmholtz free energy (pg. 153)
 - $F = E - TS$
 - Refer to duotang for equation derivation

- Definition on pg 154
- 7.4.2 – The Gibbs Free Energy (pg. 155)
 - $G = E - TS - PV$
 - Refer to duotang for derivation
 - Definition on pg. 156
- 7.4.3 – The Work Function (pg. 157)
 - $W = E - TS - \sum(u_k N_k)$
 - Refer to duotang for derivation
 - Definition on pg. 159
- 7.6-----
 - 7.6.2 – The Fundamental Equation Interface (pg. 171)
 - Refer to this for equations
 - 7.6.3 – The Condition of Equilibrium at an Interface (pg. 172)
 - Curved Interface equilibrium (pg. 175 - 176) $\Rightarrow \cos(\theta) = (O_{sv} - O_{sl}) / O_{lv}$
 - Max wetting $\Rightarrow \cos(\theta)$ maximum, θ minimum / opposite for minimum wetting. Refer to problem set 6

Chapter 8: Simple Solids

- 8.1 – Introduction (pg. 178)
 - Perfect crystal, random crystal, slightly imperfect crystal
- 8.2 – The Perfect Crystal (pg. 179)
 - 8.2.1 – The Internal Energy (pg. 179)
 - Two contributions to thermal energy: phonon vibrations and electron excitations.
 - 8.2.2 – Lattice Vibrations (pg. 180)
 - Three vibrational degrees of freedom. N atoms has 3N vibrational degrees of freedom.
 - Transverse vibrations (pg. 181 for picture). Pg 183 has the dispersion relation graph.
 - Longitudinal vibrations (pg. 184). Travels faster than transverse.
 - Vibrational modes in primitive crystal structures. FCC and BCC for example
 - Lattice vibrations in non-primitive structures.
 - 8.2.3 – The Vibrational Energy (pg. 189)
 - $E = (n + 1/2)h\nu$
 - Phonons are the elementary quantized excitations of the lattice vibrations. They are bosons
 - Derivation for the limiting cases of $\langle n(w, t) \rangle = 1 / (e^{(h\nu/Kt)} - 1)$ (pg. 189 – 190)
 - 8.2.4 – The Vibrational Contribution to the Specific Heat (pg. 190)
 - High temperature limit: Dulong-Petit Law $\Rightarrow C_v = 3Nk$
 - Low temperature limit: pg. 195 shows graph which the vibrational specific heat according to the Debye approximations. For $T > \Theta_D/2$, the heat is governed by Dulong-Petit law.
 - The stronger the bonds the higher the Debye temperature.
 - 8.2.5 – A Qualitative Version of the Debye Model (pg. 196)
 - 8.2.6 – The Electronic Contribution to the Specific Heat (pg. 198)
 - The electronic specific heat contribution is very low. Only observable at very low temperature. Negligible otherwise.
 - Their contribution is even smaller in semiconductors and insulators (pg. 202)
- 8.3 – The Random Solid Solutions (pg. 206)
 - 8.3.1 – The Bragg-Williams Model (pg. 206)
 - 8.3.2 – The Internal Energy (pg. 207)
 - Relative binding energy = $V_{ab} - 1/2(V_{aa} + v_{bb})$. It is the difference between the energy of an ab bond and the average of the energies of aa and bb bonds
 - Graph of how bonds are preferenced on pg. 208
 - 8.3.3 – The configurational Entropy (pg. 208)
 - Graph of this entropy of same page
 - 8.3.4 – The Free Energy and Thermodynamic Behavior
- 8.4 – Equilibrium Defect Conditions (pg. 211)
 - 8.4.1 – The Equilibrium Vacancy Concentration (pg. 211)
 - $X_v = e^{-(e_v/(kT))}$, e_v = formation of energy, X_v = equilibrium concentration vacancies,
 - Vacancy concentration / atom density
 - Vacancy concentration adjust to minimize Gibbs

- At moderate temperatures most solids maintain vacancy concentrations that are close to equilibrium
- At low temperatures the vacancy mobility decreases a lot. Vacancies are electrical defects in semiconductors and must be kept low to not alter the electrical properties

8.4.2 – Dislocations and Grain Boundaries (pg. 213)

Chapter 9: Phases and Phase Equilibrium

9.1 - Introduction (pg. 216)

9.2 – Phase Equilibria in a One Component System (pg. 217)

- Amorphous solids (glasses) are essentially in continuous liquid states
- Mutation: Phase relation between liquid and gas. Change occurs at particular P and T
- 9.2.1 – Phase Equilibria and Equilibrium Phase Transformations (pg. 218)
 - The internal energy increases in the order $S - L - V$. The entropy also increases in the same sequence because the system is increasingly disordered.
 - Graph of the free energies at equilibrium are found on pg. 219
- 9.2.2 – Metastability (pg. 219)
 - Explanation of the graph on previous page
- 9.2.3 – First-Order Phase Transition: Latent Heat (pg. 220)
 - First order transitions: Occur because the free energy of the product phase is lower than that of the parent phase.
 - Latent heat is positive when the transformation is from a high energy phase to a low energy phase. (liquid solidifies). Latent heat is negative when low-high energy phase.(solid melting)(more examples on page 221)

9.2.4 – Transformation from a Metastable State (pg. 221)

9.4 – Phase Equilibrium in Two Component Systems (pg. 226)

9.4.1 – The Free Energy Function (pg. 226)

- Partial derivatives of the function G
- This section covers the theorems of phase in a binary system(pg. 229)

9.4.2 – The Common Tangent Rule

- Two phase equilibria occurs when the Gibbs free energy of a two phase mixture is lower than that of either phase. Equilibrium state is that which minimizes free Gibbs Energy
- *Lever Rule* equations on page 231
- Common tangent rule on page 233

9.4.3 – The Phases Present at Given T, P (pg. 233)

9.4.4 – Equilibrium at the Congruent Point (pg. 234)

- Congruent: Have the same composition and can transform into one another without changing composition.

9.5.5 – Equilibrium at the Critical point of a Miscibility Gap (pg. 235)

- The above is the point where decomposition occurs.

9.5 – Binary Phase Diagrams (pg. 236)

9.6 – The Solid Solution Diagram (pg. 238)

9.6.1 – The Thermodynamics of the Solid Solution Diagram (pg. 238)

9.6.2 – Equilibrium Information Contained in the Phase Diagram (pg. 240)

- Eutectic diagram gives us the phase and composition and fraction of phases(given by lever rule)

9.6.3 – Equilibrium Phase Changes (pg. 241)

9.7 – The Eutectic Phase Diagram (pg. 242)

9.7.1 – Thermodynamics of the Eutectic phase Diagram (pg. 242)

9.7.2 – Equilibrium Phase Changes (pg. 244)

- Characteristic phase transformation occur is a system that has a eutectic phase diagram when it is cooled slowly enough that equilibrium phase relations are preserved.

9.7.3 – Precipitation from the alpha phase (pg. 244)

9.7.4 – The Eutectic Microstructure (pg. 245)

9.7.5 – Mixed Microstructures in a Eutectic System (pg. 246)

Chapter 10: Kinetics

10.1 – Introduction (pg. 267)

- Internal Equilibrium requires that the temperature, pressure and chemical composition have uniform values.

- Total entropy of a system should be as large as possible. State changes that result from violations are called phase transformations
 - Diffusion is a thermally activated process.
- 10.2 – Local Equilibrium (pg. 268)
- 10.3 – The Conduction of Heat (pg. 270)
- 10.3.1 – Heat Conduction in one Dimension Fourier's Law (pg. 270)
- Second law states that the temperature difference induces a flow of heat across a boundary which has different temperatures on each side of the boundary. Flow is in the direction of lower heat
 - Heat flux Equation on page 271
- 10.3.2 – Heat Conduction in Three Dimensions (pg. 272)
- General materials have 6 independent thermal conductivities.
 - Isotropic symmetry (ex. Amorphous structure). When a material is isotropic or cubic, the heat flux is parallel to the temperature gradient
- 10.3.3 – Heat Sources (pg. 274)
- The most common heat source is a chemical reaction or first order phase transition that produces latent heat
 - A phase transition to a high temperature phase in endothermic, heat is absorbed.
 - Second source is absorption or emission of radiation.
- 10.4 – Mechanisms of Heat Transfer (pg. 275)
- Three carriers: Lattice vibrations(phonons), conduction electrons or optical photons.
 - Phonons are predominant carrier at low temperatures and electrons are predominant carriers at high temperatures.
- 10.4.1 – Heat conduction by a gas of colliding particles (pg. 276)
- Equations for mean free path
- 10.4.2 – Heat conduction by mobile electrons (pg. 278)
- Primary carriers of heat in metals at normal temperatures.
 - Phonons travel at speed of sound, electrons travel at speed of light, hence electron contribute more.
 - Wiedemann- Franz law relating thermal and electric conductivity
 - The more defects and disturbances there are the less conductive. (alloys less conductive.)
- 10.4.3 – Heat Conduction by Phonons (pg. 280)
- At low temperatures and in insulators they dominate
 - Mean free path large = heat conduction, small path = less conduction
 - Lattice defects heavily disturb phonons. The phonon mean free path for collisions with solutes decreases as temperature rises.
 - Crystal is very ordered so mean free path is large so high conductivity while glass is amorphous so it has low conductivity.
 - At room temperature, metals are the best thermal conductors. The exception is with materials with very high Debye temperature like diamond
- 10.4.4 – Heat Conduction by Photons (pg. 285)
- Only apparent at very high temperatures.
 - Section explains why thermal insulators are porous compacts and how to minimize thermal radiation
- 10.6 – Diffusion (pg. 291)
- 10.6.1 – Fick's Law for the Diffusion Flux (pg. 291)
- Valid under only three conditions.
 - $D_B = D_B^0 \cdot e^{-(Q/kt)}$
 - $\Lambda = \sqrt{2D_B t}$
- 10.6.2 – Fick's Second Law for the Composition Change (pg. 292)
- 10.6.3 – Solutions of the Diffusion Equation (pg. 264)
- 10.7 – The Mechanism of Diffusion in the Solid State (pg. 297)
- 10.7.1 – The Mobility of Interstitial Species (pg. 297)
- G_m is the activation energy for atom motion. Any displacement increases the free energy of the system.
 - Diffusion requires external energy. However, atoms are in constant thermal agitation which can make them diffuse (pg. 297)

- Interstitial requires less energy than substitutional and is faster
- 10.7.2 – The Mobility of Substitutional Species (pg. 298)
 - Depends on vacancy concentration
 - Correlation effect: Random probability that that next atom jump will cancel out the previous one making both jumps useless.
 - Probability that nearest site is vacant : $W = vC_v \cdot e^{-(Q_m/kt)}$, Vacancy concentration: $C_v = A e^{-(Q_v/kt)}$
 - Pg 300 explains why Substitutional requires more energy.
- 10.7.3 – Random Walk Diffusion; Fick's second Law (pg. 300)
 - Atoms will move aimlessly throughout the solid. Net diffusional transport eventually occurs. It creates a uniform overall distribution
 - $D = D_0 \cdot e^{-(Q_D/kt)}$ (pg. 302)
- 10.7.4 – The Mean Diffusion Distance in Random Walk Diffusion (pg. 302)
 - Mean linear diffusion distance: $\Lambda = \sqrt{2Dt}$
- 10.7.5 – User of the Mean Diffusion Distance (pg. 304)
 - Two examples of uses for the equation
 - Homogenization of freshly solidified material
 - Service life of a chip which is limited by diffusion time of dopant.
- 10.8 – Microstructural Effects in Diffusion (pg. 306)
 - 10.8.1 – The Vacancy Concentration (pg. 306)
 - Quenched enhanced diffusivity: If a material is heated then cooled rapidly, the high temperature vacancies will be preserved. Consequently, diffusivity is high after cooling.
 - Deformation enhanced diffusivity: climb dislocations produce vacancies.
 - Irradiation enhanced diffusivity: Increases intensity of point defects.
 - Solute enhanced diffusivity: Like when Mg^{++} is added to NaCl to increases vacancies.
 - 10.8.2 – Grain Boundary Diffusion (pg. 308)
 - Grain boundaries are highways of diffusion.
 - At high temperature, diffusion is through the bulk, low temperatures it is through the grain boundaries
 - pg. 309 has the graph illustrating the above
 - pg. 310 has example of grain boundaries used in micro-electronics.
- Chapter 11: Phase Transformations**
 - 11.1 – Common Types of Phase Transformations (pg. 311)
 - Explains the distinct types of phase transformations
 - 11.2 – The Basic Transformations and Instabilities (pg. 312)
 - 11.2.1 – Nucleated Transformations and Instabilities (pg. 312)
 - Driving force for phase changes is decrease in Gibbs free energy.
 - Figure 11.1, explains how something requires a perturbation to change phase.
 - The most favorable transformation is the one that requires the smallest perturbation
 - To, termination limit defines the instability at which the alpha phase must transform and cannot be suppressed.
 - 11.2.2 – First Order Transitions and Mutations (pg. 314)
 - It is always possible to preserve the metastable state in these transitions. Hence, to have a transformation at equilibrium there must be nucleation.
 - Transition temperature and metastability is impossible for mutations.
 - 11.3 – Homogeneous Nucleation (pg. 314)
 - 11.3.1 – Nucleation as a Thermally Activated Process (pg. 314)
 - Nucleation is a finite fluctuation in which a small element of the parent spontaneously takes on the state that is very close to the product state.
 - Differences between homogeneous and heterogeneous nucleation on pg 315
 - Explains how the nucleus changes in size and the fact that it must overcome ΔG .
 - 11.3.2 – The Activation Energy for Homogeneous Nucleation (pg. 316)
 - ΔG relates the free energy change per unit time of the nucleus. Free energy change of the whole system.
 - Critical nucleus size is discussed here.
 - 11.3.3 – The Nucleation Rate (pg. 317)

- 11.3.4 – The Initiation Time (pg. 318)
 - Nucleation: lots of stuff forms, new phases created
 - Growth: The growth of nuclei is favored. No new phases are entered. Pg 319 has the graphs
- 11.8 – Growth (pg. 341)
 - 11.8.1 – Primary Growth and Coarsening (pg. 341)
 - Two stages: Primary growth and secondary coarsening.
 - Two things must happen for product phase to grow: must be delivered to interface and it must cross the interface.
 - 11.8.2 – Time-Temperature-Transformation(TTT) curves (pg. 342)
- 11.10 – Diffusion Controlled Growth (pg. 349)
 - 11.10.1 – Growth Controlled Thermal Diffusion (pg. 349)
 - The velocity of the interface is limited by the need to eliminate the latent heat
 - Rate of growth will happen when $T < T_m$. It can absorb latent heat. Latent heat must be removed from the interface as soon as it is generated.
 - Dendrites: pg.350-351 explains dendrites and pg 351 and 355 explains how to prevent them
 - 11.10.2 – Growth Controlled by Chemical Diffusion (pg. 351)
 - Kinetics enhanced diffusional growth
 - Constitutional Supercooling

Chapter 12: Environmental Interactions

- 12.1 – Introduction (pg. 376)
 - Reactions that change microstructure like surface hardening reaction and doping reaction in semiconductors
 - Chemical reaction between metals and oxides
 - Electrochemical reactions where electric currents assist chemical reactions
- 12.1 – Chemical Changes Near the Surface (pg. 376)
 - 12.2.1 – Thermal Treatment (pg. 376)
 - Induction Hardening: Alternating current near the metal induces current in the metal raising the temperature by joule heating. Produces hard, wear resistant surface on steel parts (austenite example)
 - Laser Surface Processing: High powered laser is shot at a material and absorbed in a very short period of time. Melts a tiny layer which is quenched creating a highly defective film making it hard and wear resistant.
 - Electron Beam Treatments: Cheaper, and have better energy transfer than lasers
 - 12.2.2 – Diffusion across the Interface (pg. 378)
 - Surface diffusion is simple and cheap. Disadvantage is that it has no flat concentration profile and needs high temperature.
 - Surface hardening: refer to page 380 (carbon nitrogen comparison)
 - Semiconductor doping: Add electrically active impurities that act as donors and acceptors. Explains how they are doped on page 381
 - 12.2.3 – Ion Implantation (pg. 381)
 - Dopant species is ionized and accelerated toward the surface by an electric field
 - Advantages of Ion vs. Diffusional on page 382
- 12.3 – Chemical Reactions at the Surface: Oxidation (pg. 383)
 - 12.3.1 – Thermodynamic of Oxidation (pg. 383)
 - Common metals have very negative ΔG at low temperatures, so they oxidize fast at room temperature. ΔG becomes less negative as temperature increases, the oxidation force decreases with temperature increases.
 - Structural alloys are the opposite. Increased oxidation at high temperatures
 - 12.3.2 – The kinetics of Oxidation (pg. 385)
 - Oxide grows as a continuous film that thickens through reactions at the interface.
 - Stresses in the growing film cause it to crack and spall off the surface as it grows. The film continuously exposed new fresh surface.
 - Parabolic Oxidation: dependant on diffusion which is low at low temperatures. pg.386 explains process
 - Linear Oxidation: pg 388-389
 - Logarithmic Oxidation: pg 389-390

- 12.3.3 – Protection against Oxidation (pg. 390)
 - Requirement for resistance is the presence of a coherent oxide film
 - Alloys can help protect if it lower the diffusion rate and therefore slows film growth or if it improves the geometric fit and permits the film to grow more without failing.
 - Protective Coating: Must be stable and must stick to material.
 - Page 391 talks about decreasing oxidation

Chapter 13: Metals (BOOK 2)

- 13.1 – The Electrical Conductivity (pg. 429)
 - 13.1.1 – Ohm's Law (pg. 429)
 - Resistivity is not a material property. Depends on length and cross-section area.
 - 13.1.2 – The Local Form of Ohm's Law: Resistivity and Conductivity (pg. 430)
 - Electric conductivity is the diffusivity that governs the net electrical flux that is induced in a potential gradient.
 - 13.1.3 – The Influence of Symmetry on the Conductivity (pg. 431)
 - Discusses the graphite example to show the symmetry
- 13.2 – The Mechanism of Conduction by Electrons (pg. 432)
 - Drift velocity is low in amorphous materials therefore conductivity is low.
- 13.3 – Conductor Type and Quality (pg. 434)
 - 13.3.1 – Band Structure and Conductor Type (pg. 434)
 - Electrons that conduct are in the valence or excited states and can move freely. Also they occupy states that are neighbored by empty states.
 - 13.3.2 – The Three Classes of Metals (pg. 436)
 - Materials that bond by ionic, polar or saturated covalent bonds are almost always semiconductors or insulators
 - The three kinds of metals are: valence band metals, band-overlap metals, transition metals.
 - 13.3.3 – The Difference in Conductivity between Classes of Metals (pg. 437)
 - Only the electrons that have energies close to the Fermi energy can become mobile in an electric field.
 - Valence-band conductor always has high mobile carrier density, while band-overlap conductors may be low or high. Transition metals are also relatively poor conductors. Pg. 438 for reason why
- 13.4 – The Influence of Temperature and Purity (pg. 439)
 - Conductivity is determined by electron density and mobility
 - 13.4.1 – The Electron Mean Free Path (pg. 439)
 - 13.4.2 – Matthiesen's Rule (pg. 440)
 - Resistivity is the reciprocal of the mean free path
 - 13.4.3 – The Thermal Resistivity of the Crystal Lattice (pg. 440)
 - Resistivity decreases to 0 as temperature goes to 0.
 - 13.4.4 – The Contribution of Solutes and Impurities (pg. 441)
 - Mean free path decreases as concentration increases
 - Scattering cross-section: Measures the probability that the impurities will affect electron movement
 - Transition metals have high scattering (pg. 442)
 - Crystal defects, dislocations, grain boundaries and atom clusters increase resistivity and phonons
 - 13.5.5 – The Total Resistivity (pg. 442)
 - 13.4.6 – The Resistivity of Alloys and two-phase mixtures (pg. 443)
 - The materials have impurities and are poor conductors.

Chapter 14: Semiconductors

- 14.1 – Introduction (pg. 444)
 - Semiconductors are used for their controllability. Especially true for extrinsic semi-conductors
 - Intrinsic behavior at high temperatures and extrinsic behavior at low temperatures.
- 14.2 – Intrinsic Semiconductor (pg. 445)
 - 14.2.1 – The Band Structure of an Intrinsic Semiconductor (pg. 445)
 - The valence band is just filled and the conduction band is just empty. $EG < 2 \text{ eV}$

- Material examples: GaAs and beta-ZnS. They typically have an even number of valence electrons.
 - Some semiconductors are not crystalline
- 14.2.2 – The Free Electron Density in an Intrinsic Semiconductor (pg. 446)
 - Fermi energy lies at the center of the band gap
 - Electron conductivity is governed by scattering process just like in metals
- 14.2.3 – Electron Holes in Intrinsic Semiconductors (pg. 447)
 - Electrons that are thermally activated into the conduction band leave a hole.
- 14.2.4 – The Intrinsic Carrier Density and the Fermi Energy (pg. 449)
- 14.2.5 – The Conductivity of an Intrinsic Semiconductor (pg. 450)
- 14.3 – Extrinsic Semiconductors (pg. 451)
 - 14.3.1 – Types of Extrinsic Semiconductors (pg. 451)
 - Charge carriers are ionization defects in crystal. Donor (n-type) and acceptor (p-type) defects
 - A substitutional element is always a donor if the valence exceeds that of the atom it replaces or an acceptor when the valence is less
 - 14.3.2 – Donors: n-type Semiconductors (pg. 451)
 - Fermi energy close to the conduction band.
 - They can free electrons
 - 14.3.3 – Acceptors: p-type Semiconductors (pg. 452)
 - Fermi energy close to valence band
 - 14.3.4 – Carrier Density in an n-type Semiconductor (pg. 453)
 - Good graph on page 456
 - 14.3.5 – Conductivity in an n-type Semiconductor (pg. 457)
 - Determined by conduction electrons
 - Conductivity increases with temperature unless it is saturated in which case it will decrease just like a metal
 - 14.3.6 – Conductivity in a p-type Semiconductor (pg. 458)
 - At low temperatures extrinsic carriers dominate because there are more holes, at high temperatures the intrinsic carriers dominate because the electrons are more mobile.
 - 14.3.7 – Compensation between Active Sites (pg. 459)
 - 14.3.8 – Degenerate Semiconductors (pg. 459)
 - Happens when there are many defects that start to overlap and form a continuous electron band or hole gap.
 - Changes to a poor metallic conductor.
 - Therefore semiconductors must be built to be extremely pure.
 - 14.3.9 – Carrier Lifetime (pg. 460)
 - Important to ensure that the carrier live long enough before they are destroyed by recombination.
 - Direct combination and impurity assisted combination.
 - GaAs is a *direct-gap* semiconductor. The minimum-energy state in the conduction band has the same wave vector as the maximum-energy state in the valence band. Hence electron-hole recombination's are relatively easy to accomplish.
 - *indirect-gap* semiconductors. The conduction band minimum and valence band maximum occur at different wavelengths. In this case, the requirement of momentum conservation has the consequence that electron-hole recombination's ordinarily require the absorption or emission of a phonon of lattice vibration. The recombination process is inefficient, and produces diffuse light.
 - Page 461 has a good explanation of why semiconductors must be very pure
- 14.4 – The P-N Junction (pg. 461)
 - 14.4.1 – The Fermi Energy at a Heterogeneous junction (pg. 461)
 - At equilibrium the Fermi energy is at the same level everywhere.
 - 14.4.2 – Response to an Impressed Potential (pg. 465)
 - Picture of N-P junction in forward bias and reverse bias
 - Current-voltage characteristic graph on page 466
 - In forward bias the net current is due to an excess of majority carriers
 - In reverse bias net current is due to minority carriers
- 14.5 – N-P-N junction (pg 467)
 - 14.5.1 – Voltage Applied at the Collector (pg. 467)

- Pg 468 for pictures
- 14.5.2 – Voltage Applied at the Base (pg. 469)
 - Picture on same page.
- 14.5.3 – Two Applications of the Bipolar Transistor (pg. 469)
- 14.6 – Metal-Insulator-Semiconductor Junctions (pg. 470)
 - Main property is the ability to invert the type of semiconductor.
 - Inversion process is explained.
 - P-type invert with positive potential, n-type with negative
- 14.8 – Metal-Oxide-Semiconductor Transistor (pg. 473)
 - Pg 474 explains how a MOSFET conducts.
 - Field effect transistors have the advantage that majority carrier conduct
- 14.9 – Processing Semiconductor Devices (pg. 475)
 - 14.9.1 – Microelectronic Devices (pg. 475)
 - 14.9.2 – The Semiconductor Chip (pg. 476)
 - Manufacturing step : Growth of crystal semiconductor: must be very pure, use the Czochralski method.
 - Explanation of why GaAs cannot be readily formed
 - 14.9.3 – Photolithography (pg. 478)
 - Selecting the doping regions. Introduced by diffusion of direct implementation. Must create the region that will be by etching out some regions.
 - 14.9.4 – Doping (pg. 479)
 - You can dope the region with a film or coating. Disadvantage explained on pg. 480
 - You can use ion implantation. Leads to more uniform doping.
 - Can use laser annealing after diffusion. Also very uniform result but it required two steps and is expensive
 - 14.9.5 – Overlaying Doped Regions to Create Junctions (pg 481)
 - 14.9.6 – Metallization (pg. 482)
 - Must connect the doped material with metal leads
 - Choose good conductors
 - Two things must be overcome: first the leads create defects so diffusion barrier must be used. Second is the patterning of the lines on a circuit.
 - The reliability of the conducting lines is also an issue. Adding a small alloy can solve the problem
 - Deposition process
 - 14.9.7 – Passivation (pg. 485)
 - An insulating film is added to protect the the components against environmental attack

Chapter 15: Insulators

- 15.1 – Introduction (pg. 486)
 - 15.1.1 – Types of Insulators (pg. 486)
 - Three types of solids: Molecular, ionic and covalent
 - Molecular: the isolation of individual molecules which are held together by polar bonds cause it to be an insulator. Electron mobility is very low
 - Large band gaps in ionic solids are due to effective localization of valence electrons on the ion cores. Ions must be mobile to be a good insulator
 - Covalent bonds like in diamonds which are used for their optical properties
 - 15.1.2 – Properties and Applications of insulators (pg. 487)
 - When a electric field is applied and removed the charge distribution keeps its distribution.
- 15.2 – The Dielectric Constant (pg. 487)
 - 15.2.1 – The Capacitance (pg. 488)
 - $Q = CV$
 - 15.2.2 – The Dielectric Permittivity (pg. 488)
 - 15.2.3 – The Electric Displacement (pg. 489)
 - $D = \epsilon \cdot E$
 - 15.2.4 – The Electric Constant (pg. 489)
 - Similar to relative permittivity : $\epsilon_r = \epsilon / \epsilon_0$
 - 15.2.5 – The Dielectric Constant of a Crystalline Solid (pg. 489)

15.3 – Polarizability (pg. 491)

15.3.1 – The Dipole Field in an Insulator (pg. 491)

- Permittivity is always greater than that of free space
- Picture on page 491 explains the alignment inside the dielectric.
- Total electric field is reduced by the re-aligning which creates its own electric field in the dielectric

15.3.2 – The Dielectric Constant of a polarized Medium (pg. 493)

- $D = \epsilon_0 E + P$

15.3.3 – The Dielectric Susceptibility (pg. 493)

15.3.4 – The atomic Polarization (pg. 493)

15.4 – Origin of the Dielectric Constant (pg. 495)

- Space charges due to diffusional rearrangement of ions
- Molecular Dipole due to the re-orientation of molecules
- Ionic dipole due to the displacement of bound ions
- Atomic dipole due to electronic charge around individual atoms

15.4.1 – Space Charges (pg. 495)

- Develops when charges particles move in response to an electric field but are prevented from migrating to the boundary of the material to produce electric current.

15.4.2 – Molecular Dipoles (pg. 496)

- First factor: depends on inherent dipole moment of molecule which increases with magnitude and separation/ dielectric constant around 10
- Second factor is the ability of the dipole to reorient itself in response to an electric field.
- The more mobile the individual atom the higher the dielectric constant.

15.3.4 – Ionic Displacements (pg. 496)

- Displacement of bond ions in the bulk of the solid. Can reach very high dielectric constants 10^3
- Imposition of an electric field causes the ions to move slightly and creates an electric field
- Responsible for the ferroelectric behavior of ionic solids.

15.4.4 – Atomic Polarization (pg. 497)

- The charge around the nucleus is slightly polarized. Small dielectric constant

15.5 – Frequency Dependence of the Dielectric Constant (pg. 498)

15.5.1 – The relaxation time for polarization (pg. 498)

15.5.2 – Relaxation Time of the Common Polarization Mechanisms (pg. 499)

- Space charges have a long relaxation time, only contributes at low frequencies.
- Molecular polarization is also long but much shorter than the previous. Negligible for frequencies above 10^8
- Ionic polarization is essentially lattice vibrations. Frequencies of up to 10^{14}
- Atomic polarization is related to the speed of electrons. Frequencies up to 10^{18}
- Graph of the step frequencies

15.7 – The Dielectric Strength (pg. 505)

15.7.1 – The Dielectric Strength and the Critical Voltage

- Critical voltage is the maximum voltage an insulator can withstand before becoming an insulator
- Cascade breakdown and thermal breakdown

15.7.2 – Cascade Breakdown (pg. 505)

- At a finite temperature, a small number of electrons are can move in response to an electric field. As the field get stronger the more electrons can ionize each other which are then accelerated by the field and the rest in a chain reaction until breakdown occurs.

15.7.3 – Thermal Breakdown (pg. 506)

- As the field increases the current density increases which causes an increase in temperature by joule heating. The temperature rise creates new carriers who will increase the temperature even more.
- The larger the insulator the greater the chance that a flaw occurs somewhere.

Chapter 16: Photonic Materials

16.1 – Introduction (pg. 521)

16.2 – Electromagnetic Waves in Free Space (pg. 525)

16.2.1 – Dipole Waves (pg. 525)

16.2.2 – The Electromagnetic Spectrum (pg. 528)

- 16.2.3 – Plane Waves and Polarization (pg. 529)
- 16.2.4 – Electromagnetic Waves as Solutions to Maxwell's Equations (pg. 531)
- 16.2.5 – Photons (pg. 532)
- 16.2.6 – Interference (pg. 533)
- 16.3 – The Propagation of Light through Solids (pg. 536)
 - 16.3.1 – Wave Propagation in Solids (pg. 536)
 - Refraction(speed of light is reduced when going through different mediums), Dispersion(white light separates into all the colors), Attenuated(reduced as it goes through a solid – Absorption+scattering), Reflection
 - 16.3.2 – Refraction (pg. 537)
 - Index of refraction, $v = c/n$
 - Refraction is not due to the slowing down of a wave but to the fact that the waves interfere with each other creating composite waves traveling at different phase velocities. (pg. 540)
 - 16.3.3 – Absorption: The Complex Refractive Index (pg. 542)
 - Page 541 talks about incident wave, reflected wave and transmitted wave.
 - Page 542 shows the intensities of these waves.
 - Page 544 talks about index of absorption
 - 16.3.4 – The Mechanism of Complex Refraction (pg. 545)
 - Absorption attenuates the incident electromagnetic wave and enhances frequency dependence
 - Two mechanisms: absorption by free charges, quantum transistors.
 - Page 549 explains absorption and reflectivity in detail.
 - Metals are opaque at visible light but transparent at higher frequencies.
 - Metals absorb light very well.
 - Page 550 talks about the absorption of insulators and semiconductors
 - 16.3.5 – Scattering of Electromagnetic Waves (pg. 551)
 - Coherent scattering: diffraction: definition on page 552
 - 2 conditions for coherent scattering on page 552
 - Incoherent scattering on page 553
 - Scattering explains why the sky is blue and the clouds are white.
 - 16.3.6 Reflection and Refraction at an Interface (pg. 555)
 - Angle of incidence equals the angle of reflection
 - Snell's Law
 - The critical angle
 - The Brewster angle
 - Rough surfaces:
 1. microroughness > very very small. A surface is optically flat as long as the height and spacing of the irregularities are smaller than the incident wave length.
 2. Roughness > 1000λ in size. Responsible for diffuse scattering which makes it difficult to transmit or reflect an image.
 3. Waviness > this can distort a reflected image
- 16.4 – Transparent Materials (pg. 565)
 - 16.4.1 – Optical glass and Gemstones (pg. 565)
 - Things needed to make a material transparent
 - How to color transparent material
 - Can use the properties of absorption in materials to prevent some frequencies from being transmitted. (Glass can absorb infrared waves)
 - 16.4.2 – Optical Fibers (pg. 566)
 - For light to propagate along a fiber, the index of refraction needs to be significantly greater than that of the surrounding medium.
 - How to lower the coefficient of attenuation
 - A major problem was the dispersion of the rays that travelled at different angles. Problem is solved by incrementing the index of refraction throughout the material.
- 16.6 – Photo emitters (pg. 574)
 - Phosphors: emit visible light when stimulated by electrons or high energy photons

- 16.6.1 – Phosphors (pg. 574)
 - Phosphors behavior on page 574, bottom of page
 - TV example here
 - Florescent light uses an electrical current to excite photon emission from the gas contained in the florescent bulb
- 16.6.2 – Light-emitting Diodes (pg. 575)
 - A P-N junction diode with an external voltage that sets it in forward bias. Electrons and holes move toward the interface and combine and annihilate there. The annihilation produces photons.
- 16.6.3 – Lasers (pg. 576)
 - Coherent : Identical frequency and phase
 - Insulated based lasers(visible band), semiconductor injection laser (infrared Band)
 - Page 576 explains how the three level laser works
 - Creating a laser beam
 - How to make the light components coherent
 - The four level laser on page 578 semiconductor laser
 - Heterojunction semiconductor lasers

Chapter 17: Magnetic Materials

- 17.1 – Introduction (pg. 580)
- 17.2 – Magnetism (pg. 581)
 - 17.2.1 – Magnetic fields (pg. 581)
 - Internal magnetic fields sources: induced by magnetic field or inherent moment.
 - Ferromagnetic is an inherent moment
 - 17.2.2 – Sources of magnetism (pg. 583)
 - Bohr magnetron
 - 17.2.3 – Magnetic Moments in Atoms (pg. 583)
 - Talks about magnetic moments in different types of materials
- 17.3 – Local Magnetic Moments in Solids (pg. 584)
 - 17.3.1 – Diamagnetism (pg. 585)
 - Refer to problem set 11
 - 17.3.2 – Paramagnetism (pg. 585)
 - Refer to problem set 11
 - Band Paramagnetism: Refer to problem set 11
 - Core Paramagnetism: Refer to problem set 11
 - 17.3.3 – Magnetic Order (pg. 586)
 - Page 587 explains the ferromagnetism, antiferromagnetism, ferrimagnetism
 - 17.3.4 – Ferromagnetism (pg. 587)
 - Due to alignment of unpaired electron spins
 - Yttrium-Iron
 - 17.3.5 – Antiferromagnetism (pg. 588)
 - Most transition metals are of this type
 - 17.3.6 – Ferrimagnetism (pg. 588)
 - Occurs is polyatomic compounds that contain ions with different core magnetic moments.
 - Ferrites
 - Fe^{+3} , Fe^{+2} magnetic stuff
- 17.4 – Ferromagnets (pg. 589)
 - 17.4.1 – Magnetic Domains (pg. 589)
 - Most useful magnetic materials are ferromagnets
 - If ferromagnetic is heated above curie point and cooled it will lose its magnetic moment
 - Annealed ferromagnetic pg. 589
 - 17.4.2 – Magnetization and magnetic hysteresis (pg. 590)
 - Coercive force: Field necessary to eliminate the magnetic moment of a ferromagnetic
 - Wide hysteresis = hard magnets, soft magnets = narrow hysteresis
 - How to achieve hard magnets is on page 591
 - How to achieve soft magnets on page 592
 - 17.4.3 – Magnetostriction (pg. 592)
 - Material spontaneously expands or contracts.

- Time varying field to a mechanical signal

Chapter 19: Mechanical Behavior

19.1 – Introduction (pg. 645)

- Strain Control
- Fractional toughness, fatigue resistance, stress corrosion, hardness of material

19.2 – Uniaxial Tension (pg. 646)

19.2.1 – The Load-Displacement Curve (pg. 646)

- Load displacement curve: depends on characteristic and geometry
- The load required to achieve a given displacement increases with a cross-sectional area of the bar

19.2.2 – The Engineering Stress-Strain Curve

- Engineering Stress: $s = P/A$, P: load, A: cross-sectional area
- Engineering Strain: $e = L/L_0$, L: elongation, L_0 : specimen length
- Elastic deformation (region which is recoverable), Stable plastic deformation (region just before material breaks), The Yield Strength (maximum stress before plastic deformation), Unstable plastic deformation (where the material will eventually break), ultimate tensile strength (breaks).
- Elongation, post necking elongation

19.2.3 – True Stress and True Strain (pg. 652)

- True stress takes into account the necking effect which changes cross-sectional area
- True strain page 653

19.2.4 – Verities of Tensile Behavior

- Some materials (metals and alloys) have well defined yield points while others do not yield but extend until failure (brittle)
- Brittle and elastic materials simply fracture

19.4 – Fracture (pg. 659)

19.4.1 – Fracture Toughness (pg. 659)

- Measures resistance to fracture
- Depends on size of crack and material property

19.4.2 – Plane Strain Fracture Toughness (pg. 660)

- The fracture toughness (resistance to fracture) decreases as the plate thickness increases

Chapter 21: Plastic Deformation

21.1 – Introduction (pg. 686)

- Deformation can always be described as the as the sum of a change in volume and a change in shape at constant volume, shear

21.1.1 – Engineering Significance of Plastic Deformation (pg. 685)

- Want to avoid it, used to shape materials, plastic instability, diagnostics

21.1.2 – Mechanisms of Plastic Deformation (pg. 686)

- Dislocation plasticity, Diffusion, Structural Transformations (mechanical twinning), Tumbling.

21.2 – The Yield Strength (pg. 687)

- Stress that is needed to move dislocations to cause significant plastic deformation.

21.1.2 – Deformation by Dislocation Motion (pg. 687)

- Shear caused by edge dislocation. Is directed perpendicular to the dislocation line

21.2.2 – The Critical Resolved Shear Stress (pg. 689)

- Good example of shearing and how bonds must be reconnected (pg. 690)
- Critical resolved stress
- Slip System

21.2.3 – The Tensile Yield Strength of a Single Crystal (pg. 691)

- Condition to initiate plastic deformation
- Tensile yield strength is not a material property
- Preferred slip planes for FCC, BCC, HCP

21.2.4 – The Yield Strength of a Polycrystal (pg. 692)

- Local yielding, general yielding
- Two features of yielding in polycrystals pg. 693

21.3 – Microstructure Control of the Yield Strength (pg. 694)

- The value of shear stress is controlled by placing obstacles of the plane of dislocation that make it difficult to move

21.3.1 – Structural Hardening: The pN stress (pg. 694)

- Super strong structures are usually brittle (diamond)
- 21.3.2 – Grain Refinement (pg. 696)
 - Refine grain size to harden material
 - Smaller grain size = hard material
- 21.3.3 – Obstacle Hardening (pg. 697)
 - Employ microstructural obstacles that inhibit dislocation slip
 - Pg. 699 for conclusions
- 21.3.4 – Solution Hardening (pg. 699)
 - Interstitial solutes are better than substitutional solutes
 - More effective in BCC
 - The yield point
- 21.3.5 – Dislocation Hardening (pg. 701)
 - Heat treatment, mechanical deformation, transformation strengthening
- 21.3.6 – Precipitation Hardening (pg. 704)
- 21.4 – The Influence of Temperature and Strain Rate (pg. 706)
 - 21.4.1 – The Variation of Yield Strength with Temperature (pg. 706)
 - Low temperature strength
 - Intermediate temperature strength
 - High temperature Strength
 - 21.4.2 – The Influence of Strain rate on Strength (pg. 708)
- 21.5 – Work Hardening (pg. 708)
- 21.6 – Plastic Instability, Necking and Failure (pg. 711)
 - 21.6.1 – The Considered Criterion (pg. 711)
 - 21.6.2 – Tensile Elongation (pg. 713)
 - The simplest way to increase elongation is to decrease the yield strength.
 - Can be increased by decreasing the extent of early yielding
 - Can be increased by increasing the work hardening rate in the later stages of deformations.
 - Dual phase steels

Chapter 22: Fracture

- 22.1 – Introduction (pg. 716)
 - 22.1.1 – Engineering Importance (pg. 716)
 - 22.1.2 Why things Fall apart (pg. 717)
 - Necking
 - Buckling
 - Unstable crack propagation
- 22.2 – Fracture Mechanics (pg. 718)
 - 22.2.1 – Crack Propagation from a pre-existing Flaw (pg. 718)
 - The Critical Fracture Stress
 - 22.2.2 – The Fracture Toughness (pg. 721)
 - Plane strain fracture toughness
 - Two reasons why K_{IC} is the best measure of toughness
 - 22.2.3 – Fracture Sensitive Design (pg. 723)
- 22.3 – Microstructure Control of Fracture Toughness (pg. 725)
 - 22.3.1 – The Fracture Mode (pg. 726)
 - Intergranular fracture
 - Transgranular cleavage
 - Ductile Fracture
 - 22.3.2 – Choice of Fracture mode: The Ductile Brittle Transition
 - 22.3.3 – Suppressing brittle Fracture
 - 22.3.4 – Raising the toughness in a ductile mode
 - 22.3.5 – Raising the fracture stress in a brittle mode
 - Eliminating flaws
 - Compressive stress
 - Crack growth resistance