Chapter 10
Bonding: Molecules and Solids

10.1 When Atoms Come Together

- Consider two finite square wells. What are the four lowest-energy wavefunctions (two degenerate pairs) when the wells are far apart?

- When the two wells move closer together, which wavefunction is the higher energy? Why?

- Why is it fair to say that, when atoms are close together, electrons no longer belong to one atom or another but to the entire collection?

10.4 Crystalline Solids

- What is a crystal lattice?

- Do all solids form crystals? If not, give a counterexample.

- What is the typical spacing between atoms in a crystalline material?

- Describe/identify the *simple cubic*, *body-centered cubic*, *face-centered cubic*, and *hexagonal close-packed* lattices.

- Distinguish between *covalent*, *ionic*, *metallic*, and *molecular* solids.

- What is the *London force*?

- Why are metallic solids so malleable, with relatively low melting points? Why are they such good conductors?

10.5 Energy Bands and Electrical Conduction

- Describe how the energy level n of a finite square well divides into a band of N energy levels when you have N finite square wells in close proximity. What do the wavefunctions look like for these energy levels? Which wavefunction has the highest energy? The lowest?

- As you move to lower energy levels in a single band, how does the *kinetic energy* change? How does the *potential energy* change? Which changes more?

- What is a *band gap*, and what causes it?

- What is the wavenumber k of the wavefunction at the top of the nth band? At the bottom of the nth band?

- Does the width of each band depend on the number of atoms, or the spacing between atoms? Why?

Electrical Conduction

- How does the graph of energy versus wavenumber deviate from the parabolic $E = \frac{1}{2m}\hbar^2 k^2$.

- Why is the average *collision time* of a conduction electron much larger than classical physics would predict?

- According to quantum mechanics, what causes resistance?

10.6 Conductors, Insulators, and Semiconductors

- In a lattice of atoms, why don't the lowest energy levels form a band, as they do in a lattice of finite square wells.

- How many electrons can each band hold, if there are N atoms?

- What are the *conduction band* and the *valence band*?

- How are these two bands populated in a conductor and an insulator?

- Why isn't beryllium an insulator, even though it has 4 electrons per atom?

- What is the difference in band structure between an insulator and a semiconductor?

- What is the *conductivity gap*?

- How does the conductivity of a semiconductor depend on the size of the band gap and the temperature?

- Where is the Fermi energy in a conductor, insulator, and semiconductor?

10.7 Semiconductor Theory

- What is a *diode*?
- What are *holes*? Where do they exist? How are they created?
- How does the energy of a hole change as it moves to higher energy levels?
- What is *doping*? Why is it useful?
- What is the difference between an *n-type* semiconductor and a *p-type* semiconductor?
- What is a *donor state*? *Acceptor state*?
- What are *majority carriers*?

10.8 Semiconductor Devices

- Explain why current only flows in one direction in a *p–n junction*. Which direction?
- What do the energy bands look like in an unbiased p–n junction.
- What can a transistor do in a circuit? Explain the role of the *collector*, *base*, and *emitter*.
- Explain how a transistor works in terms of energy bands.

10.9 Superconductors

- What are the properties of a *superconductor*?
- What is the significance of the *critical temperature*? How about the *critical field*?
- What happens to a magnet placed next to a superconductor?
- What happens to a *Type-II superconductor* when the field is too high?
- What do electrons do to cause superconductivity?