2.4 CHAPTER SUMMARY

- Silicon contains four atoms in its last orbital. It also contains a small number of free electrons at room temperature.
- When an electron is freed from a covalent bond, a "hole" is left behind.

- The bandgap energy is the minimum energy required to dislodge an electron from its covalent bond.
- To increase the number of free carriers, semiconductors are "doped" with certain impurities. For example, addition of phosphorus to silicon increases the number of free electrons because phosphorus contains five electrons in its last orbital.
- For doped or undoped semiconductors, $np = n_i^2$. For example, in an n-type material, $n \approx N_D$ and hence $p \approx n_i^2/N_D$.
- Charge carriers move in semiconductors via two mechanisms: drift and diffusion.
- The drift current density is proportional to the electric field and the mobility of the carriers and is given by $J_{tot} = q(\mu_n n + \mu_p p)E$.
- The diffusion current density is proportional to the gradient of the carrier concentration and given by $J_{tot} = q(D_n dn/dx - D_p dp/dx)$.
- A pn junction is a piece of semiconductor that receives n-type doping in one section and p-type doping in an adjacent section.
- The pn junction can be considered in three modes: equilibrium, reverse bias, and forward bias.
- Upon formation of the pn junction, sharp gradients of carrier densities across the junction result in a high current of electrons and holes. As the carriers cross, they leave ionized atoms behind, and a "depletion region" is formed. The electric field created in the depletion region eventually stops the current flow. This condition is called equilibrium.
- The electric field in the depletion results in a built-in potential across the region equal to $(kT/q)\ln{(N_A N_D)/n_i^2}$, typically in the range of 700 to 800 mV.
- Under reverse bias, the junction carries negligible current and operates as a capacitor. The capacitance itself is a function of the voltage applied across the device.
- Under forward bias, the junction carries a current that is an exponential function of the applied voltage: $I_S[\exp(V_F/V_T) - 1]$.
- Since the exponential model often makes the analysis of circuits difficult, a constant-voltage model may be used in some cases to estimate the circuit's response with less mathematical labor.
- Under a high reverse bias voltage, pn junctions break down, conducting a very high current. Depending on the structure and doping levels of the device, "Zener" or "avalanche" breakdown may occur.