SUMMARY

Section 1–1

- According to the classical Bohr model, the atom is viewed as having a planetary-type structure with electrons orbiting at various distances around the central nucleus.
- Bohr model. The electrons can be waves or particles and precise location at any time is uncertain.
- The nucleus of an atom consists of protons and neutrons. The protons have a positive charge and the neutrons are uncharged. The number of protons is the atomic number of the atom.
- Electrons have a negative charge and orbit around the nucleus at distances that depend on their energy level. An atom has discrete bands of energy called *shells* in which the electrons orbit. Atomic structure allows a certain maximum number of electrons in each shell. In their natural state, all atoms are neutral because they have an equal number of protons and electrons.
- The outermost shell or band of an atom is called the *valence band*, and electrons that orbit in this band are called *valence electrons*. These electrons have the highest energy of all those in the atom. If a valence electron acquires enough energy from an outside source, it can jump out of the valence band and break away from its atom.

Section 1–2

- Insulating materials have very few free electrons and do not conduct current under normal circumstances.
- Materials that are conductors have a large number of free electrons and conduct current very well.
- Semiconductive materials fall in between conductors and insulators in their ability to conduct current.
- Semiconductor atoms have four valence electrons. Silicon is the most widely used semiconductive material.
- Semiconductor atoms bond together in a symmetrical pattern to form a solid material called a
- *crystal*. The bonds that hold the type of crystal used in semiconductors are called *covalent bonds*.

Section 1–3

- The valence electrons that manage to escape from their parent atom are called *conduction electrons* or *free electrons*. They have more energy than the electrons in the valence band and are free to drift throughout the material.
- When an electron breaks away to become free, it leaves a hole in the valence band creating what is called an *electron-hole pair*. These electron-hole pairs are thermally produced because the electron has acquired enough energy from external heat to break away from its atom.
- A free electron will eventually lose energy and fall back into a hole. This is called *recombination*. Electron-hole pairs are continuously being thermally generated so there are always free electrons in the material.
- When a voltage is applied across the semiconductor, the thermally produced free electrons move toward the positive end and form the current. This is one type of current and is called electron current.
- Another type of current is the hole current. This occurs as valence electrons move from hole to hole creating, in effect, a movement of holes in the opposite direction.

Section 1–4

- An *n*-type semiconductive material is created by adding impurity atoms that have five valence electrons. These impurities are *pentavalent atoms*. A *p*-type semiconductor is created by adding impurity atoms with only three valence electrons. These impurities are *trivalent atoms*.
- The process of adding pentavalent or trivalent impurities to a semiconductor is called *doping*.

- The majority carriers in an *n*-type semiconductor are free electrons acquired by the doping process, and the minority carriers are holes produced by thermally generated electron-hole pairs.
- The majority carriers in a *p*-type semiconductor are holes acquired by the doping process, and the minority carriers are free electrons produced by thermally generated electron-hole pairs.

Section 1–5

- A *p*-*n* junction is formed when part of a material is doped *n*-type and part of it is doped *p*-type. A depletion region forms starting at the junction that is devoid of any majority carriers. The depletion region is formed by ionization.
- The barrier potential is typically 0.7 V for a silicon diode and 0.3 V for germanium.

KEY TERMS

Key terms and other bold terms are defined in the end-of-book glossary.

Atom The smallest particle of an element that possesses the unique characteristics of that element.

Barrier potential The amount of energy required to produce full conduction across the *p*-*n* junction in forward bias.

Conductor A material that easily conducts electrical current.

Crystal A solid material in which the atoms are arranged in a symmetrical pattern.

Doping The process of imparting impurities to an intrinsic semiconductive material in order to control its conduction characteristics.

Electron The basic particle of negative electrical charge.

Free electron An electron that has acquired enough energy to break away from the valence band of the parent atom; also called a *conduction electron.*

Hole The absence of an electron in the valence band of an atom.

Insulator A material that does not normally conduct current.

Ionization The removal or addition of an electron from or to a neutral atom so that the resulting atom (called an ion) has a net positive or negative charge.

Metallic bond A type of chemical bond found in metal solids in which fixed positive ion cores are held together in a lattice by mobile electrons.

Orbital Sub-shell in the quantum model of an atom.

***PN* junction** The boundary between two different types of semiconductive materials.

Proton The basic particle of positive charge in the nucleus.

Semiconductor A material that lies between conductors and insulators in term of conductive properties. Silicon, germanium, and carbon are examples.

Shell An energy band in which electrons orbit the nucleus of an atom.

Silicon A semiconductive material.

Valence Related to the outer shell of an atom.

Assignment

Select True/False for each statement

Answers can be found at www.pearsonhighered.com/floyd.

1. An atom is the smallest particle in an element.
2. An electron is a negatively charged particle.
3. An atom is made up of electrons, protons, and neutrons only.
4. Electrons are part of the nucleus of an atom.
5. Valence electrons exist in the outer shell of an atom.
6. Semiconductor crystals are formed by the bonding of atoms.
7. Pure silicon is a good conductor.
8. A *p-n* junction is formed from silicon when both *p* and *n* materials are used on opposite sides of a crystal.
9. The *p* and *n* regions are formed by a process called ***ionization.***
10. The band gap in a *p-n* junction is measured in ohms.
11. The band gap can vary depending on temperature.

SELF-TEST Please select the correct answer.

Answers can be found at www.pearsonhighered.com/floyd.

Section 1–1

1. Every known element has

(a) the same type of atoms **(b)** the same number of atoms

(c) a unique type of atom **(d)** several different types of atoms

2. An atom consists of

(a) one nucleus and only one electron **(b)** one nucleus and one or more electrons

(c) protons, electrons, and neutrons **(d)** answers (b) and (c)

3. The nucleus of an atom is made up of

(a) protons and neutrons **(b)** electrons

(c) electrons and protons **(d)** electrons and neutrons

4. Valence electrons are

(a) in the closest orbit to the nucleus **(b)** in the most distant orbit from the nucleus

(c) in various orbits around the nucleus **(d)** not associated with a particular atom

5. A positive ion is formed when

(a) a valence electron breaks away from the atom

(b) there are more holes than electrons in the outer orbit

(c) two atoms bond together

(d) an atom gains an extra valence electron

Section 1–2

6. The most widely used semiconductive material in electronic devices is

(a) germanium **(b)** carbon **(c)** copper **(d)** silicon

7. The difference between an insulator and a semiconductor is

(a) a wider energy gap between the valence band and the conduction band

(b) the number of free electrons

(c) the atomic structure

(d) answers (a), (b), and (c)

8. The energy band in which free electrons exist is the

(a) first band **(b)** second band **(c)** conduction band **(d)** valence band

9. In a semiconductor crystal, the atoms are held together by

a) the interaction of valence electrons **(b)** forces of attraction

c) covalent bonds **(d)** answers (a), (b), and (c)

10. The atomic number of silicon is

(a) 8 **(b)** 2 **(c)** 4 **(d)** 14

11. The atomic number of germanium is

(a) 8 **(b)** 2 **(c)** 4 **(d)** 32

12. The valence shell in a silicon atom has the number designation of

(a) 0 **(b)** 1 **(c)** 2 **(d)** 3

13. Each atom in a silicon crystal has

(a) four valence electrons

(b) four conduction electrons

(c) eight valence electrons, four of its own and four shared

(d) no valence electrons because all are shared with other atoms

Section 1–3

14. Electron-hole pairs are produced by

(a) recombination **(b)** thermal energy **(c)** ionization **(d)** doping

15. Recombination is when

(a) an electron falls into a hole

(b) a positive and a negative ion bond together

(c) a valence electron becomes a conduction electron

(d) a crystal is formed

16. The current in a semiconductor is produced by

(a) electrons only **(b)** holes only **(c)** negative ions **(d)** both electrons and holes

Section 1–4

17. In an intrinsic semiconductor,

(a) there are no free electrons

(b) the free electrons are thermally produced

(c) there are only holes

(d) there are as many electrons as there are holes

(e) answers (b) and (d)

18. The process of adding an impurity to an intrinsic semiconductor is called

(a) Doping **(b)** recombination **(c)** atomic modification **(d)** ionization

19. A trivalent impurity is added to silicon to create

(a) Germanium **(b)** a *p*-type semiconductor

(c) an *n*-type semiconductor **(d)** a depletion region

20. The purpose of a pentavalent impurity is to

(a) reduce the conductivity of silicon **(b)** increase the number of holes

(c) Increase the number of free electrons **(d)** create minority carriers

21. The majority carriers in an *n*-type semiconductor are

(a) Holes **(b)** valence electrons **(c)** conduction electrons **(d)** protons

22. Holes in an *n*-type semiconductor are

(a) minority carriers that are thermally produced

(b) minority carriers that are produced by doping

(c) majority carriers that are thermally produced

(d) majority carriers that are produced by doping

Section 1–5

23. A *p*-*n* junction is formed by

(a) the recombination of electrons and holes b) ionization

(b) the boundary of a *p*-type and an *n*-type material c) the collision of a proton and a neutron

24. The depletion region is created by

(a) Ionization (b) diffusion **(c)** recombination (d) answers (a), (b), and (c)

25. The depletion region consists of

(a) nothing but minority carriers (b) positive and negative ions

(c) no majority carriers (d) answers (b) and (c).