CHAPTER 12

From semiconductors to solid state devices

Answers to revision questions

1. Electric conductivity relates to the total number of electrons in the conduction energy band. A metal has its conduction energy band and valence energy band merged together. This means as many electrons in the valence band will be in the conduction band. This results in a full conduction band, hence good conductivity. A semiconductor at room temperatures only has its conduction band partially filled by the electrons jumping from the valence band across a relatively small forbidden energy gap. This lower number of electrons accounts for the lower conductivity of the semiconductor. An insulator has virtually no electrons in the conduction band due to the large forbidden energy gap (no electron can jump from the valence band into the conduction band), hence the conductivity of an insulator is the lowest.

2. (a) The factors that influence the size of the drifting velocity is the size of the current, the density of the electron and the cross-sectional area of the conductor ($v = \frac{I}{neA}$).

   (b) Three times the diameter means that the area will be nine times larger. Therefore, according to the equation, the drifting velocity will be $\frac{1}{9}$ in the wire that has a larger diameter.

   (c) The actual velocities of the electrons are all in random directions, therefore the net effect is much smaller.

3. The resistance of the conductor decreases as now there are fewer collisions as a result of the lower temperature. The resistance of a semiconductor will increase as there are now fewer electrons reaching the conduction band due to the lower energy (temperature).

4. Intrinsic semiconductors are pure semiconductors.

5. Doping with a group III element; doping with a group V element.

6. (a) The definition can be found in Chapter 12.

   (b) n-type semiconductors are created by doping the pure semiconductors with a group V element such as phosphorus. The doped semiconductors will have excessive free electrons, therefore enhanced conductivity.

   (c) p-type semiconductors are produced by doping the pure semiconductors with a group III element such as boron. The doped semiconductors will now have positive holes, and hence enhanced electrical properties.

   (d) When an n-type and a p-type semiconductor are joined together, the excessive electrons from the n-type semiconductor will migrate towards the positive holes in the p-type semiconductor at the junction. As a result, the n-type will be lacking electrons, so it is positive, whereas the p-type will now have gained extra electrons, so it is negative.

   (e) The device is called a diode. The function of a diode is to allow electric currents to flow only in one direction.

7.

Thermionic devices	Solid state devices
Diode valve	Diode
Triode valve	Transistors
Important electronic devices in early days	Important electronic devices in modern society
Big	Small, especially with integrated circuits
Fragile	Tough
Use more energy	Use less energy
Can not be integrated on a large scale	Can be integrated to give rise to microprocessors

8. The text has given a few reasons, so refer to it for this question.

9. This question requires a detailed explanation. It is essential that students are comfortable in explaining the phenomenon in full paragraphs. However, only a brief comment is made in the answers. For detail, please see Chapter 12.

   (a) Electric fields are created by the fact that when a p-type semiconductor is joined with an n-type semiconductor. The p-type becomes negative and the n-type becomes positive, hence an electric field is produced at the junction.

   (b) When the UV light reaches the junction, it knocks free the electrons at the junction, hence the photoelectric effect.

   (c) The electricity is created as these free electrons are accelerated by the junctional electric field created by the n-type and the p-type. The electrons will be accelerated towards the positive n-type semiconductor and away from the negative p-type semiconductor.

10. This is a typical open-ended response question. A full answer will not be provided here, however a suggested structure is as follows:

   - Introduce the definition of semiconductors.
   - Briefly describe how semiconductors are used as simple electronic devices such as diodes.
   - Describe how semiconductors are used in integrated circuits. Give a brief explanation of integration.
   - Explain how integrated circuits are important for the electronic industries. You should include microchips when talking about electronics and computers.
   - Explain how continually improving integration will result in more powerful, smaller and cheaper electronic devices and computers.
   - Explain how these may impact on human society in the areas such as medicine, research, military and economics.