Homework 10

PHYSICS 304
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Chapter 12 (B)

1. At $T = 0$, a metal with a half-filled band can still conduct as an external electric field is being applied. The electric field "gives" some energy to the electrons, allowing them to flow.

2. When a photon is absorbed, an electron is excited from the valance band to the conduction band with that photon's energy and a hole is created in the valance band.

3. (a) If the gap is $1.14\,\text{eV}$, the photon would have that same energy,

$$\begin{aligned} f &= E/h \\ &= \frac{1.14\,\text{eV}}{4.135 \times 10^{-15}\,\text{eV} \cdot \text{s}} \\ &= 2.75 \times 10^{14}\,\text{Hz} \end{aligned}$$

   (b) For the wavelength for that photon,

$$\begin{aligned} f\lambda &= c \\ \lambda &= c/f = \frac{3 \times 10^{8}\,\text{m} \cdot \text{s}^{-1}}{2.75 \times 10^{14}\,\text{Hz}} \\ &= 1.1\,\mu\text{m} \quad \text{(near-infrared)} \end{aligned}$$

4. The light is absorbed by electrons in silicon with energies that exceed the minimum energy (the gap energy). In diamond, the light is able to pass without absorption since the light does not have enough energy to excite electrons from the valance band.

5. For wavelengths under $1\,\mu\text{m}$, the maximum energy from those photons would be $1.24\,\text{eV}$. Probably the germanium would be a better choice, as the energy required is much less than silicon, and lower energy photons would have a higher chance of exciting electrons in germanium.

6. For the energy gap of $5.5\,\text{eV}$, the photons corresponding to that energy would have a wavelength

$$\begin{aligned} \lambda &= \frac{c}{f} = \frac{hc}{E} \\ &= \frac{1240\,\text{eV} \cdot \text{nm}}{5.5\,\text{eV}} = 225\,\text{nm} \end{aligned}$$

   At wavelengths shorter than that, the energy would exceed $5.5\,\text{eV}$ and would allow the absorption of photons by valance electrons.

7. Sample A is a semiconductor.

   Sample B is a conductor.

   In semiconductors, more electrons are held within the conduction band as the temperature increases.

8. (a) In a p-type semiconductor, the Fermi energy is lowered at a level near the upper edge of the valance band. This is since the semiconductor is doped with trivalant atoms.

   (b) In n-type semiconductors, the Fermi level is raised near the conduction band. The doped atoms donate additional electrons, lowering the energy gap required for electrons to populate the conduction band.

9. (a) At the junction boundary (the depletion zone), some electrons from the n-type material will move into the holes in the p-type semiconductor, as it's more energetically favorable. This will create a potential difference at the junction.

   Additionally, the levels will shift, such that the Fermi levels are at an equal level on both sides.

   (b) The electrons will move right, from the n-type to the p-type.

   (c) The p-type will move up and the n-type will move down, until a point where the Fermi levels are equal on both sides.

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