Photonics, Spring 2025

Submit your answers as a PDF file via Google Classroom before deadline (31.03.2025 at 10.00).
If problems, contact the course assistant joonas.mustonen@helsinki.fi.
If you utilize LLM models as assistance in solving the task, please specify their usage at the end of your submission.

Exercise 8, 24.3.2023

This week's exercises have to do with some fundamental concepts relating to semiconductors, including electron energy levels and the accompanying statistics (**Optoelectronics and Photonics: Chapter 3**).

1. Transistors and Photonics (2 points)

Transistors are fundamental components in electronics, acting as **switches** or **amplifiers**. Their operation relies heavily on semiconductor physics, particularly the control of charge carrier flow (electrons and holes) via junctions. Photonics involves the interaction between photons and electrons, often employing transistors as essential components for controlling electronic signals triggered by light.

a) Explain the difference between transistors BC547 and BC557. Instead of listing all features, focus on
i) how does the physical principle differ and
ii) for which kind of different applications, they are designed to (low-side switching vs. high-side switching).

b) Consider a simplified phototransistor circuit used in a photonic application, where an NPN phototransistor is activated by incident photons (light). The phototransistor requires a minimum photon energy equal to or greater than its semiconductor bandgap energy to generate electron-hole pairs effectively. Here, Silicon is used as semiconductor material (E_g = 1.12 eV). Does the incident photon activate the phototransistor effectively, if it is illuminated with the visible light?

2. Fundamental concepts relating to semiconductor (4 points)

In the context of semiconductors, define/describe the following briefly but thoroughly:

a) Density of states (DOS)
b) Fermi-Dirac function
c) The product and it's integral
d) Degenerate and nondegenerate semiconductors, and how Boltzmann statistics relates to the latter

3. Electrons in the CB of a nondegenerate semiconductor (3 points)

a) Consider the energy distribution of electrons in the conduction band (CB) in a nondegenerate semiconductor. Assuming that the density of state and using Boltzmann statistics , show that the energy distribution of the electrons in the CB can be written as:

   where is the electron energy in terms of measured from , and is a constant at a given temperature (independent of).
   Hint: Introduce an arbitrary constant based on the proportionality argument for . Try then to arrive at the desired form by introducing multiplier terms in the form .
b) Setting arbitrarily , plot . Where is the maximum and what is the FWHM of the curve?

c) Show that the maximum in the energy distribution is at or at *Hint: It is a short derivation, if you consider the right function that relates x and E.*