Exercise 2 (online: 01.05.2023. Return by: **Mo 08.05.2023 10:00**) **6P**

1. **p-n-Diode: II** 6P

   The qualitative description of the current-voltage characteristic of the previous exercise can also be considered from a microscopic viewpoint. In such a microscopic model the current densities of the charge carriers within both the conduction and valence band must be considered. For simplicity we consider initially only the currents within the conduction band.

   (a) Electrons which are thermally activated from the valence band to the conduction band over the energy gap E_g inside the depletion region of the p-type material will be accelerated in the electric field between the p- and n-contacts. A particle current density J_e^{gen}, the so-called "generation current density" arises. By which function can the temperature dependence of this current density be expressed (give as a proportionality, without pre-factors)? How will an applied voltage affect such a "generation current density"? (2P)

   (b) Electrons from the n-type region can only diffuse into the p-type contact if they have sufficient thermal energy so that they can overcome the potential barrier between the two regions. This so-called "recombination current density" is therefore given by: $J_e^{\text{rec}} \propto \exp\left(-e\Delta\phi_o/k_BT\right)$. How will the above expression be modified if, in addition, one applies the voltage U to the junction? (1P)

   (c) In the absence of an applied voltage these two currents will compensate each other exactly: $J_e^{\text{rec}}|_{U=0} = J_e^{\text{gen}}$, which establishes a link between $\Delta\phi_o$ and E_g. What is expected for the current density as a function of the applied bias $J_e^{\text{rec}}(U)$, and what is expected for the total current density J_e?(2P)

   (d) An analogous consideration leads to an estimation of the "hole" current density in the valence band. Write it down. What is the total current density $J = J_e + J_h$? (1P)