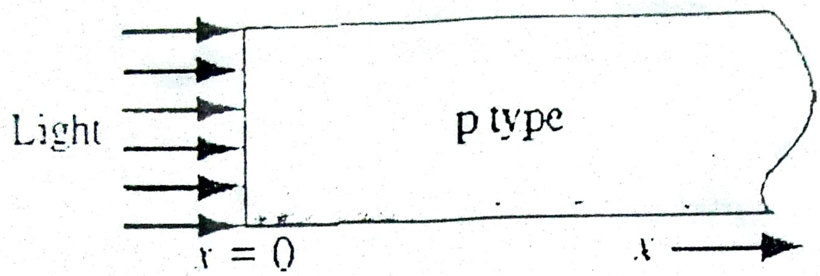
Assignment -1

1. The bottom of the conduction band at one end of a silicon resistor is at the same energy level as the top of the valence band at other end. What current flow through the resistor, if the resistance is 1.12 kΩ?
2. What is the importance of sheet resistance in designing Integrated circuit resistors? P-type doped semiconductor layer has approximately uniform acceptor $N_A = 5 \times 10^{16}$ cm^{-3} and thickness is 4 μm. calculate the sheet resistance if hole mobility is $\mu_p = 450$ $cm^2/V\text{-}s$.
3. N-type silicon substrate with $N_D = 10^{15}$ cm^{-3} is to be converted into P-type by boron diffusion, so that the resistivity at 75° C is $\rho = 5$ Ω-cm. What should be the doping level? What is the resistivity at room temperature? The hole mobilities at 75° C and at room temperature are 341 $cm^2/V\text{-}s$ and 467 $cm^2/V\text{-}s$, respectively. The intrinsic carrier concentration at 75° C is $n_i = 2.9 \times 10^{11}$ cm^{-3}.
4. A 2-cm long silicon piece, with cross-sectional area of 0.1 cm^2, is used to measure the electron mobility. What is the electron mobility if 90 Ω of resistance is measured and the doping level is known to be $N_D = 10^{15}$ cm^{-3}? Neglect any contact resistance.
5. (a). The channel of a 0.1 μm MOSFET can be considered as a resistor with length L = 0.1 μm. Because the channel is short, the electrons drift through the channel with the saturation velocity (v_{sat} = 0.1 $\mu m/ps$) when the nominal voltage is applied across the channel. How long does it take an average electron to drift across the whole channel?
(b). The MOSFET channel is connected by a 5-mm long copper track to another device. How long does it take an average electron to drift the distance between the two devices connected by the copper track if the current that the electrons conduct is 10 mA? The cross section of the strip is 0.1 μm^2, and the number of free electrons in copper is $n_{Cu} = 8.1 \times 10^{22}$ cm^{-3}.
(c). Based on the speed of light in vacuum ($c = 3 \times 10^8$ m/s), estimate the time that it takes an electromagnetic wave to propagate along the MOSFET channel and along the 5-mm copper track. Based on the results, answer the following question: Does the drift velocity impose the limitation to the speed of signal/energy propagation? If not, what is the meaning of drift velocity?
6. Two n-type Si samples ($N_D = 10^{15}$ cm^{-3})are exposed to light, which in both samples generates E-H pairs at a rate of $G_{opt} = 10^{19}$ $cm^{-3}s^{-1}$. The minority carrier lifetime in the first sample is τ_p = 100 μs, where as minority carrier lifetime in the second sample is τ_p = 100 ns by intentionally introduced R-G centers. For each sample, determine
(i). the steady-state excess concentration of holes, δp
(ii). how long it takes for δp to drop by 10% when the light is switched off

(iii). How long it takes for δp to drop to the value that is 10% higher than the thermal equilibrium level.

7. Consider a bar of p-type silicon material that is homogeneously doped to a value of 3×10^{15} cm^{-3} at T = 300K. The applied electric field is zero. A light source is incident on the end of the semiconductor as shown below.



The excess carrier concentration generated at x=0 is $\delta p(0) = \delta n(0) = 10^{13} cm^{-3}$.
Assume the following parameters (neglect surface effects):

μ_n = 1200 $cm^2/V\text{-}s$ $\quad\quad$ τ_{n0} = 5×10^{-7} s

μ_p = 400 $cm^2/V\text{-}s$ $\quad\quad$ τ_{p0} = 1×10^{-7} s

(a) Calculate the steady-state electron and hole concentrations as a function of distance into the semiconductor.

(b) Calculate the electron diffusion current density as a function of x.

8. Consider the semiconductor described in Problem 7. Assume a constant electric field E_o is applied in the +x direction.

(a) Derive the expression for the steady-state excess-electron concentration (Assume the solution is of the form e^{-ax}).

(b) Plot δn versus x for E_o = 0 and 12V/cm.

(c) Explain the general characteristics of two curves plotted in part (b).