MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.012 ELECTRONIC DEVICES AND CIRCUITS

Problem Set No. 1

Issued: September 5, 2003 **Due:** September 12, 2003

Reading Assignments:

Lecture 1	(9/4/03)	-Chap. 1 (all), Chap. 2 (all)
Lecture 2	(9/9/03)	-Chap. 3 (all except 3.3.2), App. B
Lecture 3	(9/11/03)	-Chap. 4 (all)
Lecture 4	(9/16/03)	-Chap. 5 (all)
Lecture 5	(9/18/03)	-Chap. 6 (all)
Lecture 6	(9/23/03)	-Chap. 7 (7.1,7.2)

Problem 1 - This problem concerns the following five samples of silicon, each of which has a different doping level:

(a) 10^{17} cm^{-3} antimony
(b) 10^{16} cm^{-3} boron, 5 x 10^{15} cm^{-3} phosphorous
(c) no dopants
(d) 5 x 10^{16} cm^{-3} antimony, 10^{15} cm^{-3} boron
(e) 5 x 10^{15} cm^{-3} arsenic, 10^{16} cm^{-3} antimony (be careful of this one)

For each of these samples determine

(i) the conductivity type, n- or p-type or intrinsic, and the net doping level,
(ii) n_o and p_o, the thermal equilibrium carrier concentrations at room temperature, and
(iii) $_o$, the resistivity in thermal equilibrium at room temperature.

Assume that at room temperature the electron mobility, μ_e, is 1600 cm^2/V-s, the hole mobility, μ_h, is 600 cm^2/V-s, and the intrinsic carrier concentration, n_i, is 10^{10} cm^{-3}.

Problem 2 - Do Part (b) of Problem 2.2 in the course text.

Problem 3 - Do Problem 3.5 in the course text.

Problem 4 - Do Problem 3.7 in the course text.

Problem 5 - Do Parts (a) thru (d) of Problem 3.9 in the course text.

Problem 6 - This question concerns a photoconductive light detector made of p-type silicon in which $N_A = 10^{16}$ cm^{-3}, $\mu_e = 1500$ cm^2/V-s, $\mu_h = 600$ cm^2/V-s, $_e = 10^{-5}$ s, and $n_i = 10^{10}$ cm^{-3}. Take the upper limit for low level injection to be p' = n' = 0.1 p_o.

a) This silicon sample is known to contain 8 x 10^{15} cm^{-3} arsenic atoms and an unknown concentration of one, and only one, other dopant element. What is the concentration of this other element, and suggest one possible element it might be (there may be several possibilities; only give one).

b) What is the conductivity of this sample in thermal equilibrium, $_o$?

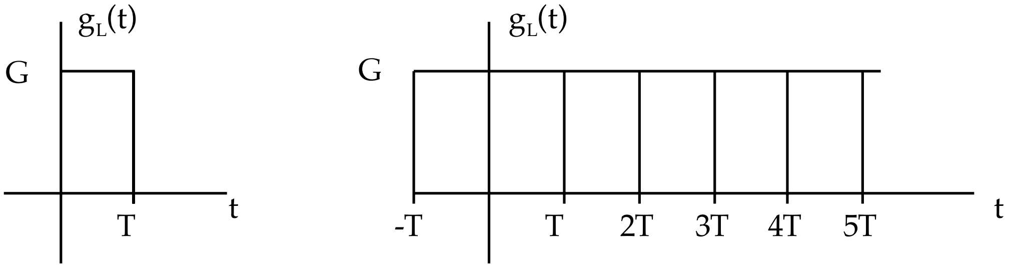
c) Suppose that we what to use this detector in an linear analog optical communications system, meaning we want to always operate under low level injection conditions. Suppose further that our electronics can reliably detect changes in conductivity, ' (≡ - $_o$), as small as 0.01% (i.e., '/ $_o \geq 10^{-4}$).

i) What is the minimum optical generation rate, G_L, we can detect? Assume uniform optical generation throughout the sample.

ii) What is the maximum uniform optical generation rate, G_L, we can have in our system without getting out of the linear regime?

d) Now suppose we want to use this detector in a digital system where we we want to detect a data stream consisting of pulses (corresponding to ones), and the absense of pulses (corresponding to zeros). (In this application one would of course ultimately want to measure ', but we will focus on n' in this part of the question to avoid the complexity of also finding '.)

A typical pulse is illustrated on the left below:



i) What is n' after a long string of ones like that illustrated on the right above? Assume G is not so large that it forces the sample out of low level injection conditions.

ii) How small can T be if we want to be certain we will detect a single pulse coming after a long series of zeros, if we assume that in order to determine that we have detected a one we require that n' must have increased to over 60% of the value you found in (i) above by half-way through the pulse (i.e., by T/2 after the onset of the pulse)? With this T will we also be certain to detect a zero after a long string of ones? Explain.