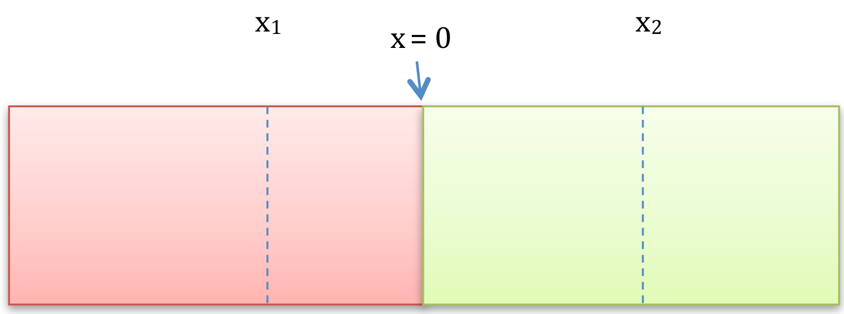
Problem 2:

A p-n junction is formed by bringing two pieces of crystalline silicon (c-Si) into contact as shown below. Phosphorous atoms, at a concentration of 5.0×10^{15} cm^{-3}, are dopants on the left side, while boron atoms are dopants on the right at a concentration of 3.0×10^{16} cm^{-3}. For both the phosphorus-doped and boron-doped sides, the dopant atoms are distributed uniformly. Note that the drawing may not be to scale. The device is in the dark, and all of the dopants are ionized. The region $x_1 < x < x_2$ is the depletion region.

a. Define (and describe in words) variables N_A and N_D



b. Label the drawing above to clearly to indicate which side is the p-type silicon, and which is the n-type silicon.

c. What is the source of the charge density and the value of the charge density (in Coulombs per cm^3, to two significant figures) at $x = x_1/2$?

d. If we take the intrinsic carrier concentration to be 1.0×10^{10} cm^{-3}, what is the value of the built-in potential (V_{bi}) to two significant figures? Calculate and graph V_{bi} as a function of temperature over the range of temperatures experienced by North America: http://en.wikipedia.org/wiki/Extremes_on_Earth As always, clearly label your axes, and include units.

e. Use the dielectric constant of silicon to calculate the electric field gradient, $\partial E/\partial x$, at $x = x_1/2$? Express your answer in units of V/cm^2. Explain how the dielectric constant of Si is related to the permittivity of free space.

f. Calculate the values of x_1 and x_2 in cm. What fraction of the device thickness is in the depletion region if the total thickness of the solar cell is 200 μm thick?

g. Check whether or not we have charge neutrality (i.e., zero net charge) over the region from x_1 to x_2. Recall that we have no free carriers (electrons or holes) in this region.

h. Write the equations needed to solve for the electric field strength over the region x_1 to x_2. Specify the boundary conditions and use these to solve the equations. Compute and graph the electric field as a function of position from x_1 to x_2. Label your axes, including appropriate units for the x- and y-axes. What is the value of the electric field for $x < x_1$, outside the depletion region?

i. Solve for the potential as a function of position, and graph the results from x_1 to x_2 (define the potential to be equal to zero at $x = x_2$). Label the axes appropriately, and add any additional detail required to demonstrate understanding. Look at the value of the potential change from one side of the depletion region to the other. Is this physically realistic (briefly explain your answer)?

j. With this potential profile, a photon is absorbed within the depleted region. Which way do the electron and hole move under the influence of the electric field? Use an 'e-' and an 'h+' along with arrows to show their drift directions.