Helpful Equations:

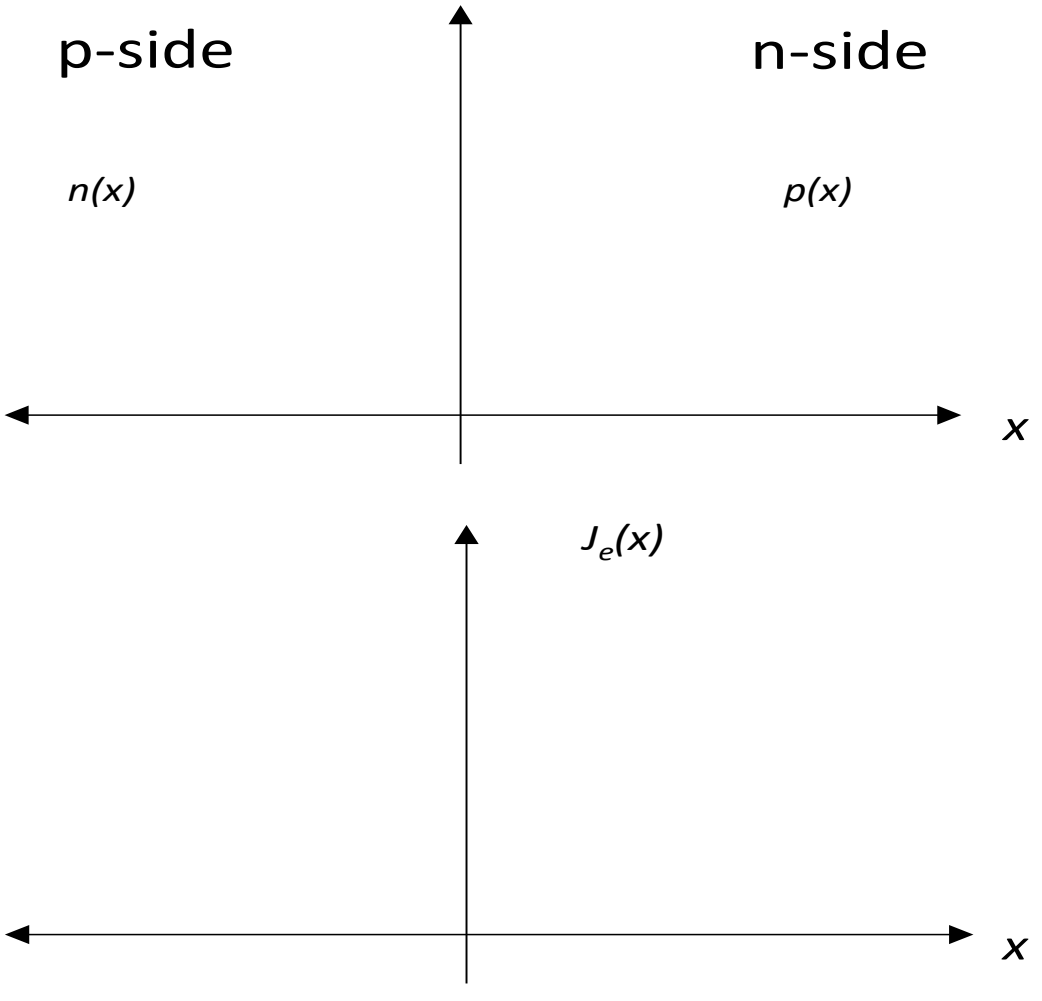
$$J_e(x) = q \cdot D_e \cdot \frac{dn}{dx}$$

Problem #1 - 7 points

For a forward-biased pn junction diode with applied voltage V_D and doping concentrations of N_A on the p-side and N_D on the n-side ($N_A > N_D$),

a) Make a large sketch of the minority carrier concentration plot. Assume that the lengths of both the n-side and p-side are much bigger than the electron and hole "length constants" L_e and L_h . Be sure to label the value of the minority carrier concentrations at the edges of the depletion region. Make any differences between the p-side and n-side obvious.

b) Make a large sketch of current density $J_e(x)$ due to electron flow. Be sure to provide an expression for the current density at the edge of the depletion region on the p-side.

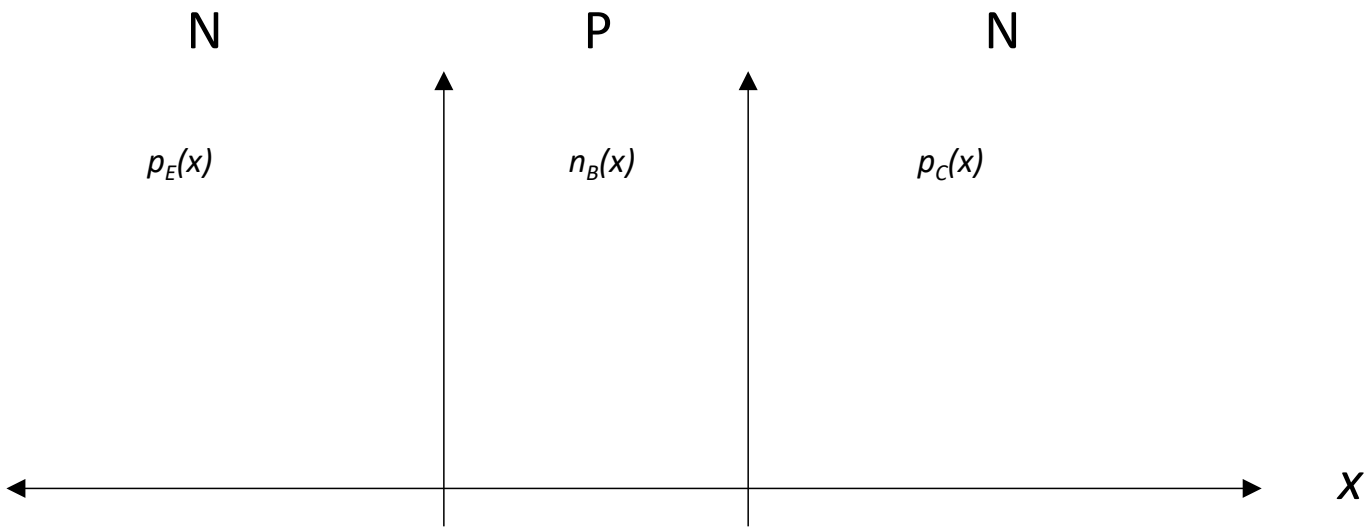


Problem #2 - 6 points

For a NPN bipolar junction transistor operating in **saturation** ($V_{BE} > 0$ and $V_{BC} > 0$) Assume that the emitter has a high doping concentration (ND) and that the base and collector regions are lightly and identically doped.

a) Draw the minority carrier concentration plot in the emitter, base, and collector regions, providing equations for the concentrations at the depletion region edges. When there are differences in the equilibrium levels and depletion region widths between regions, make it obvious in your plot. (Note: please use the n-region on the left as the emitter)

b) Explain why $V_{CE} = 0.2V$ is commonly used to denote the edge of saturation?



Problem #3 - 7 points – p-type MOS capacitor

a) From an electrostatic perspective, explain why a p-type MOS capacitor with an aluminum gate shorted to the p-type bulk (V_{GB} = 0V) is different from a block of p-type material without the gate and oxide? Assume that

$\phi_p < \phi_{\text{Aluminum}} < 0$ Note that $\phi_p = -V_T \ln\left(\frac{N_A}{n_i}\right)$

b) Sketch the charge distributions that are present in the MOS capacitor when the gate material is shorted to the p-type bulk.

c) Sketch the electrostatic potential as a function of x, from the gate to the far right side of the p-type material.