1. Consider a piece of Si 1 µm thick, 1 µm wide, and 10 µm long. It is doped with a donor concentration of \( N_D = 10^{17} \text{ cm}^{-3} \).
   
   a) What is the electron mobility?
   b) What is the sheet resistance of the material?

   A voltage \( V \) is applied between the two 1 µm x 1 µm faces.

   c) What is the resistance of the piece?
   d) Plot the current through the Si as a function of \( V \) for \(-15 < V < 15\). Remember to account for velocity saturation at \( v_{sat} = 10^7 \text{ cm/s} \).

2. We have a piece of Si doped at \( N_D = 2 \times 10^{16} \text{ cm}^{-3} \).
   
   a) Find \( n_o \) and \( \mu_e \).
   b) We want this piece of Si to have \( n_o = 10^{15} \text{ cm}^{-3} \). What are the type and magnitude of the dopants we need to add? What is the new electron mobility?
   c) We have a new piece of Si which we want to dope to \( n_o = 10^{16} \text{ cm}^{-3} \) and have \( \mu_e = 950 \text{ cm}^2/\text{V}s \). Find \( N_A \) and \( N_D \).

3. We have a 2 µm x 5 µm x 10 µm piece of undoped Si.
   
   a) How many holes are in it?
   b) The Si is now doped with \( N_D = 10^{12} \text{ cm}^{-3} \). How many holes are in it?
   c) What is the minimum volume you need to guarantee 1 hole in the doped Si of part b)?
   d) If the Si is heated (say, by having currents running through it), what happens to the number of holes in it? What happens to the number of electrons in it? How does this affect the current in it for a fixed applied voltage?
The following problem was originally on PS2, but was postponed until this problem set:

4. Integrated resistor

To make a resistor on an integrated circuit, a spiral of poly is often laid out on a chip to produce the resistive circuit element between two nodes (a and b here) as shown to the left.

Assume the following: poly width is 5\(\mu\)m; poly in this spiral configuration provides a resistance of 1k\(\Omega/\mu\)m; and capacitance per area to the underlying substrate is 0.15aF/\(\mu\)m\(^2\). For this analysis, neglect the contact connections a and b.

(a) How many squares will be needed to realize a 2.5MO resistor? What is then the resulting area of the resistor?
(b) The spiral layout can be modeled as a simple RC circuit connecting points a and b. Compute the value of capacitance and draw this RC circuit, assuming that the underlying substrate is grounded.
(c) Using SPICE only, consider the following circuit:

Generate a Bode magnitude plot of \(V_{out}/V_{in}\) using the following for the 2.5MO resistor:
(i) an ideal 2.5MO resistor
(ii) the series-RC model of the spiral resistor you found in part (b)