Problem 1: Miller indices and diamond lattice crystal structure (20 points)

The properties of semiconductors depend upon the crystalline orientation of the channel surface. A channel surface with higher atomic density is advantageous for hole transport. Given that the lattice constant of Si is 5.43Å, calculate the areal density of atoms (number/cm^2) on each of the following planes: (100), (110), and (111). Based on your answers, which plane would you expect to be best for hole transport?

Problem 2: Density of states in one dimension. (20 points)

Show that the density of states of a free electron in one dimension is $D_1 = \frac{1}{\pi\hbar}\left(\frac{2m}{E}\right)^{\frac{1}{2}}$

Problem 3: Carrier Concentrations (20 points)

Consider a Si sample under equilibrium conditions, doped with Boron to a concentration 10^{17} cm^{-3}. At T = 300K, is this material n-type or p-type? What are the majority and minority carrier concentrations?

Problem 4: Resistivity and Resistance (20 points)

a) Consider a Si sample maintained at T = 300K under equilibrium conditions, doped with Boron to a concentration 2×10^{16} cm^{-3}:

- **i)** What are the electron and hole concentrations (n and p) in this sample? Is it n-type or p-type?
- **ii)** Suppose the sample is doped additionally with Phosphorus to a concentration 6×10^{16} cm^{-3}. Is the material now n-type or p-type?

b) Ultra-thin semiconductor materials are of interest for future nanometer-scale transistors, but can present undesirably high resistance to current flow. How low must the resistivity of a semiconductor material be, to ensure that the resistance of a 2nm-thick, 10nm-long, 100nm-wide region does not exceed 100 ohms?

Problem 5: Low-k dielectric (20 points)

Search and read the literature to plot the change of dielectric constant (k) as a function of time or technology nodes for interlayer dielectrics in microprocessors.