1. Please explain the following words. (25%)
   a. subthreshold slope
   b. early effect
   c. body effect
   d. gradual channel approximation
   e. drain-induced barrier lowering

2. A sample of silicon at \( T = 150K \) is doped with boron at a concentration of \( 1.5 \times 10^{15} \text{cm}^{-3} \) and with arsenic at a concentration of \( 8 \times 10^{14} \text{cm}^{-3} \). (a) Is the material n or p type? (b) Determine the electron and hole concentrations. (c) Calculate the total ionized impurity concentration. (15%)

3. Describe two different junction (p-n junction) breakdown mechanisms? (10%)

4. Consider an n-channel MOSFET with \( W = 15 \text{um} \), \( L = 2 \text{um} \), and \( C_{ox} = 6.9 \times 10^{-8} \text{F/cm}^2 \). Assume that the drain current in the nonsaturation region for \( V_{DS} = 0.10 \text{V} \) is \( I_D = 35 \text{uA} \) at \( V_{GS} = 1.5 \text{V} \) and \( I_D = 75 \text{uA} \) at \( V_{GS} = 2.5 \text{V} \). Determine the inversion carrier mobility from above experimental results. (10%)

5. Please draw (a) the cross section of an idealized one-dimensional p-n-p bipolar transistor under the active mode of operation. (It is required to mark all bias and current flow in the figure.) (b) Doping profiles and the depletion regions under active mode conditions (c) Electric-field profile and (d) Energy band diagram. (It is required to mark all energy levels.) (20%)

6. For a bipolar junction transistor (BJT), the current gain generally varies with collector current. A representative plot is shown in Fig. P6. Please explain why the current gain \( h_{FE} \) increases first and then decreases with \( I_C \). (10%)

![Graph of current gain vs collector current](image)

**Fig. P6**

7. (a) Define what is meant by short-circuit current in a pn junction solar cell. Define what is meant by open-circuit voltage in a solar cell. (b) Sketch the I-V characteristics of a solar cell. Define what is meant by the maximum power rectangle of a solar cell? (10%)