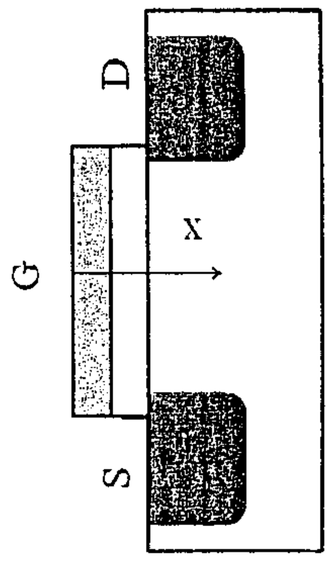
科目：固態電子元件(300H)　　校系所組：清華大學電子工程研究所

1. For a p-channel MOSFET device with cross-section shown in **Fig. 1**, plot its energy band diagram along the **x-direction** while in (a) accumulation, (b) depletion and (c) inversion, respectively. (15%)

Fig. 1



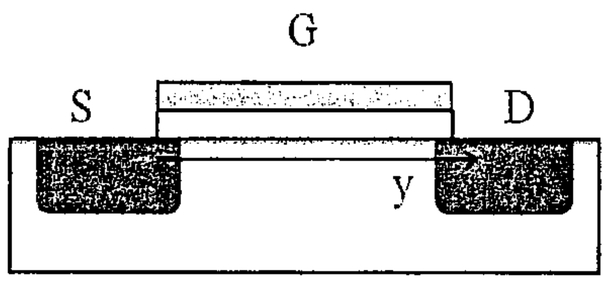


Fig. 2

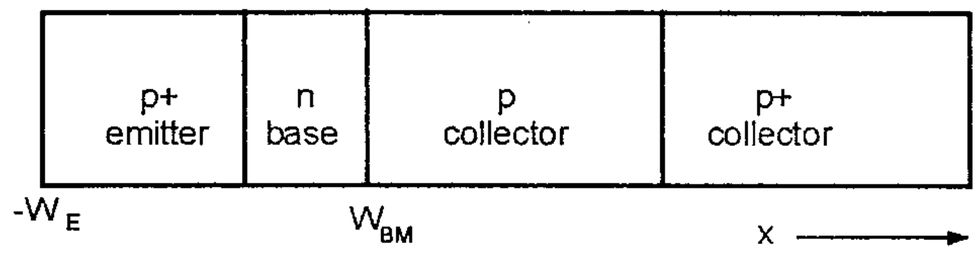
2. For a n-channel MOSFET device with cross-section shown in **Fig. 2**, plot its energy band diagram along the **y-direction** under the following assumptions.
   (a) At low V_D(~ 50mV) for long and short channel devices, respectively. (5%)
   (b) At high V_D(~V_{DD}) for long and short channel devices, respectively. (5%)
   (c) Explain drain-induced barrier lowing effect with the plot in (b). (5%)

3. (a) Write the diffusion current equation of a silicon P/N junction (reverse current is I_R, and the external voltage is V_A). (2%)
   (b) Follow (a), if qVA >> kT, derive the forward current swing of P/N junction is 60mV/decade at 25C. (2%)
   (c) Follow (b), what is the operation temperature (°C) if 45mV/decade at forward mode? (3%)
   (d) Follow (c), consider the recombination-generation current, what is the swing (mV/decade) at small forward? (3%)

4. Consider uniform doped P/N junction with N-type concentration, $N_D = 10^{17}$ cm^{-3}, and P-type concentration N_A is $9x10^{17}$ cm^{-3}.
(a) When the work function of P-type is 4.9eV and N-type is 4.15eV. What is the build-in voltage V_{bi}? (2%)
(b) If V_A = -1V (reverse bias), what is the total junction voltage drop (V)? (2%)
(c) When the total depletion width is 1.6μm, what is the depletion width (μm) in P-type region? (3%)
(d) What is the maximum electrical field (E_{max})? (3%)

5. Draw the energy band diagram (Ec, Ev, Ei, EF) for a PNP transistor in **Fig. 3** at the following conditions,
(a) at Thermal equilibrium and no bias (3%)
(b) at Saturation mode (4%)
(c) at Early effect (4%)
(d) at Kirk's effect (4%)

Fig. 3



注意:背面有試題

科目：固態電子元件(300H)　　校系所組：清華大學電子工程研究所

6. Please describe what carrier drift velocity and carrier mobility are. Write down the typical values of mobility for both carriers in lightly doped Si at room temperature and calculate the drift velocity for both carriers when the Si is subject to an electric field of 10^4 V/cm. Please remember to include units for all physical quantities. (15 %)

7. Please explain what dielectric relaxation is and estimate the order of magnitude of dielectric relaxation time for an n-type Si doped to $10^{17}cm^{-3}$. You need to explain how to calculate the dielectric relaxation time and write down the detailed calculation process, including, for example, the resistivity. Use all typical values for the physical quantities you need, such as carrier mobilities. Please remember to include units for all physical quantities. (20%)