本試題是否可以使用計算機： ☑可使用 ， □不可使用 （請命題老師勾選）

1. Density of states $N(E)$ is the number of available electronic states per unit volume per unit energy around the energy E. Accounting for spin, the density of states in a three dimensional system is $N(E) = \frac{\sqrt{2} m^{3/2} E^{1/2}}{\pi^2 \hbar^3}$. Derive $N(E)$ in a 2-D system (as quantum well) and in a 1-D system (as quantum wire). (10%, 10%)

2. Assume an abrupt junction of n- and p- type Silicon, with the doping concentrations N_D 5×10^{18} cm^{-3} and N_A 2×10^{15} cm^{-3}. The intrinsic carrier density of Si is 1×10^{10} cm^{-3} at temperature 300 K. The permittivity and dielectric constant of Si are ε_0: 8.854×10^{-12} (farads/meter) and 11.9. Calculate the built-in voltage and the width of the depletion region. (15%)

3. Consider two energy levels E_1 and E_2 of an atom, where E_1 corresponds to the ground state and E_2 corresponds to the excited state. Einstein identified three radiative processes expressed by

$$\frac{dn_2}{dt} = -A_{21}n_2 + B_{12}n_1\rho(\nu) - B_{21}n_2\rho(\nu) = -\frac{dn_1}{dt}$$

, where n_2 and n_1 are the populations of E_2 and E_1. The coefficients of A_{21}, B_{12}, B_{21} correspond to the radiative rates of spontaneous emission, absorption and stimulated emission. By Plank formula, the electromagnetic energy density inside a cavity at the central frequency of interest ν is

$$\rho(\nu) = \left(\frac{8\pi n^3 \nu^2}{c^3}\right)\frac{h\nu}{e^{h\nu/kT} - 1}$$

, where $h\nu = E_2 - E_1$. Using classic Boltzmann statistics $n_2/n_1 = \exp(-h\nu/kT)$, find out $\frac{A_{21}}{B_{21}}$ and $\frac{B_{12}}{B_{21}}$. (15%)

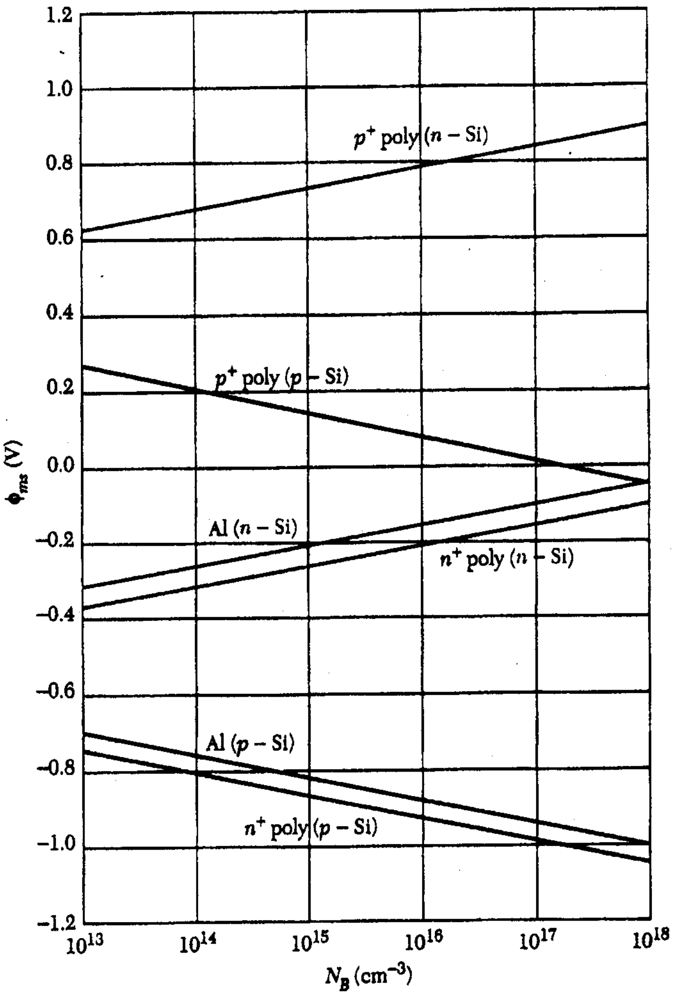
4. Germanium has bandgap E_g = 0.66 eV, dielectric constant ε_r = 15.8, and electron effective mass $m_e = 0.1\ m_0$, where m_0 is real mass of an electron. Find the donor ionization energy. (10%)

5. A heterojunction bipolar transistor (HBT) has a bandgap of 1.5 eV for the emitter and 1.35 eV for the base. A bipolar junction transistor (BJT) has a bandgap of 1.35 eV for both the emitter and base materials. The emitter doping is 10^{17} cm^{-3} and base doping is 10^{15} cm^{-3} for BJT. If the HBT has the same emitter doping and the same common-emitter current gain β_0 as the BJT, find the base doping of HBT. Assume T = 300 K and all other device parameters are the same. (15%)

（背面仍有題目.請繼續作答）

本試題是否可以使用計算機： ☑可使用 ， □不可使用 （請命題老師勾選）

6. Consider the work function difference as a function of background impurity concentration shown below. For an n-channel n^+-polysilicon-SiO_2-Si MOSFET with substrate doping $N_A = 10^{17}$ cm^{-3} and fixed oxide charge $Q_f/q = 4\times10^{11}$ cm^{-2}, calculate the threshold voltage V_T of this device if the gate oxide thickness is 4 nm. Assume T = 300 K and intrinsic carrier density of Si is 10^{10} cm^{-3}. (15%)



7. An n-channel GaAs MESFET has a tungsten contact. The barrier height of W-GaAs diode is 0.9 V. The n-channel doping is 3×10^{15} cm^{-3} and the channel thickness is 0.5μm. Calculate the pinch-off voltage of this MESFET. Assume T = 300 K and the dielectric constant of GaAs is 12.4. (10%)