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Mark the correct answer(s) or closest answer for the following multiple-choice questions of Problems 1 to 5 in the separate answer sheet. Show your reasoning or work. Note that there would be no credits without proper work.

1. At room temperature, the intrinsic carrier concentration of silicon is $1.5x10^{10}/cm^3$. A silicon sample is uniformly doped with arsenic atoms of $10^{15}/cm^3$. Which of the following statement(s) is or are correct? (4 %)

(a) Since arsenic are donors, the hole concentration will be $1.5x10^{10}/cm^3 + 2.25x10^5/cm^3 \approx 1.5x10^{10}/cm^3$

(b) Since arsenic are acceptors, the electron concentration is $1.5x10^{10}/cm^3 + 10^{15}/cm^3 \approx 10^{15}/cm^3$

(c) As the temperature decreases, fewer arsenic impurities ionize and both electron and hole approach the intrinsic carrier concentration.

(d) By adding uniformly phosphorous atoms of $10^{15}/cm^3$ to this arsenic-doped silicon sample, the sample becomes compensated and both electron and hole approach the intrinsic carrier concentration.

(e) None of the above.

2. The measured electron mobility obtained in a Hall effect experiment is 1800 cm^2/V-s in a semiconductor. The electron mobility due to lattice scattering in this semiconductor is 3000 cm^2/V-s. What will be the electron mobility due to impurity scattering in this semiconductor? Show your work. (4 %)

(a) 7500 cm^2/V-s

(b) 4500 cm^2/V-s

(c) 3000 cm^2/V-s

(d) 1500 cm^2/V-s

(e) 1200 cm^2/V-s

(f) None of the above

參考用

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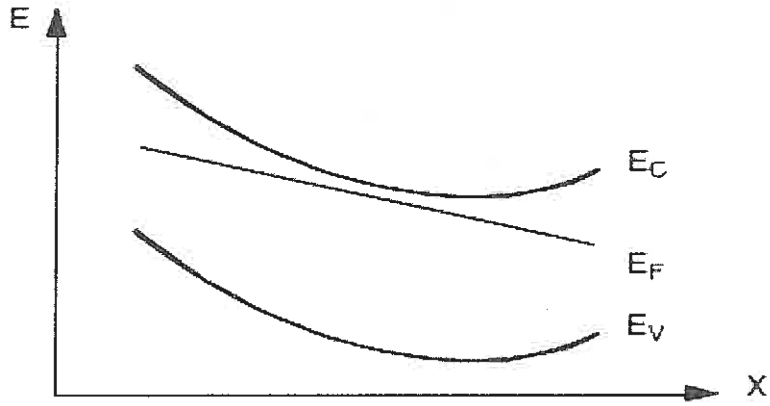
3. For a semiconductor with an energy band diagram shown below, which of the following conditions is correct? Show your work or reasoning. (4%)



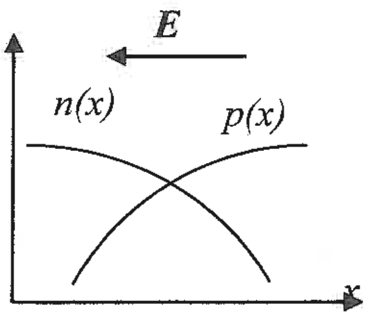
	Uniformly Doped	External Electric Field	Current Density
(a)	yes	no	= 0
(b)	yes	yes	> 0
(c)	yes	yes	< 0
(d)	no	no	= 0
(e)	no	yes	> 0
(f)	no	yes	< 0
(g)	None of the above		

4. Given the carrier concentration distributions and the applied electric field shown in the figure, fill in the blanks with arrows to indicate the correct directions of current density (J) and flux (Φ) flow. (4%)

Φ_n^{drift} (   )

Φ_p^{diff} (   )

J_n^{diff} (   )



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5. Plot a Fermi-Dirac distribution function at temperature T=300 K from E=2 eV to 3 eV and the Fermi level E_F = 2.5 eV. Note that kT=25.9 meV at 300 K. Repeat it for T=0 K. (5 %)

6. The band gap energy of Silicon is around 1.12 eV at room temperature at normal atmosphere. Place a piece of silicon in the bottom of deep ocean, where the water temperature is around 38F and the pressure can reach 200 atmospheres. Would the band gap energy increase, decrease or stay the same as 1.12 eV? Show your work to elucidate the effects of temperature and pressure on the band gap energy. Note that there would be no credits without proper work. (6 %)

7. A piece of silicon at room temperature and at thermal equilibrium is doped with 10^{17}/cm^3 acceptors. It has been subjected to different excitations. Draw energy band diagrams corresponding to: (i) the sample is uniformly illuminated, to steady state, with light having photon energies much less than the band gap energy of silicon (ii) the sample is uniformly illuminated, to steady state, with light having photon energies much higher than the band gap energy of silicon. In addition, the illumination intensity is strong enough to induce an excess carrier density about 5% as much as the majority carriers density and (iii) continued with Condition (ii), the light is turned off at time t=0, draw the corresponding energy band diagram at time t, which is 3 times minority carrier lifetime. (8 %)

8. Consider one long-channel and one short-channel NMOSFETs, both with V_G=V_D at all time. Both devices have same threshold voltage, V_T., answer the following questions. (15%)

   (a) Sketch I_D vs. V_{GS}-V_T for both devices qualitatively on the same plot. Explain the I_D vs. V_{GS}-V_T dependency by equations. [Assume that carriers reach saturation velocity in the short-channel device. (8%)

   (b) Sketch g_m vs. V_{GS}-V_T for both devices qualitatively on the same plot. Explain this dependency by equations. (7%)

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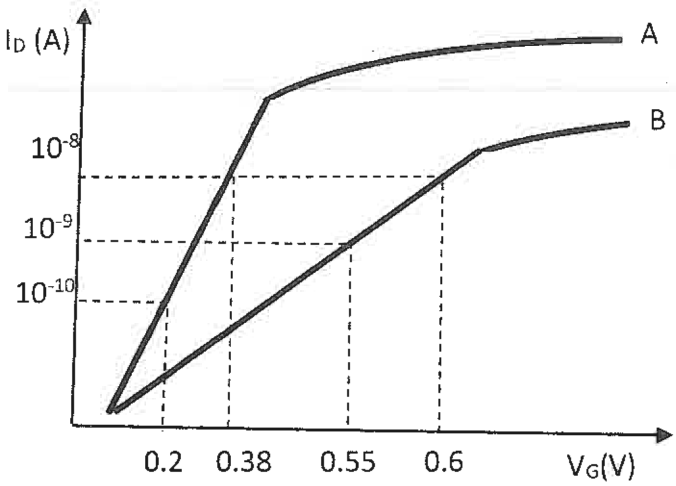
9. The I_D-V_G characteristics of two different MOSFETs (A and B) are shown in following figure. Please answer the following questions. (20%)

(a) Find the Sub-threshold Swing of the two devices, respectively. (8%)

(b) Assume that the two devices are identical except gate oxide thicknesses, find the thickness ratio of the two devices, i.e. Tox(A)/Tox(B).(4%)

(c) Which device will subject to more severe body effect and why? Propose two methods for reducing its body effect. (8%)



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10. The energy band diagram given below characterizes a Si step PN diode at room temperature. Note that $2.3kT/q = 0.06$ V and $n_i = 1 \times 10^{10}$ cm^{-3} at $T = 300$ K (room temperature).

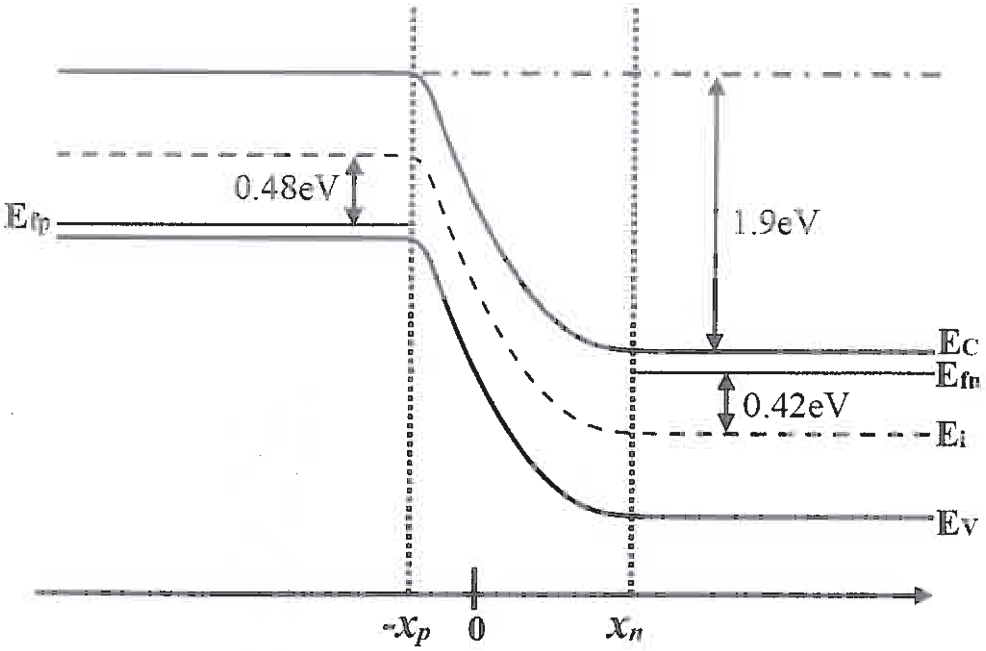
(a) Is this diode forward or reverse biased? (3%)

(b) What is the built-in potential of this diode? (3%)

(c) What is the magnitude of the bias voltage? (3%)

(d) What is the doping concentration of the P region? (3%)

(e) What is the doping concentration of the N region? (3%)



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11. The excess carrier distributions Δn/n and Δp/p in the quasineutral regions of a PNP bipolar junction transistor (BJT) at room temperature are sketched below. Note that $2.3kT/q = 0.06$ V and $n_i = 1 \times 10^{10}$ cm^{-3} at $T = 300$ K (room temperature). Determine

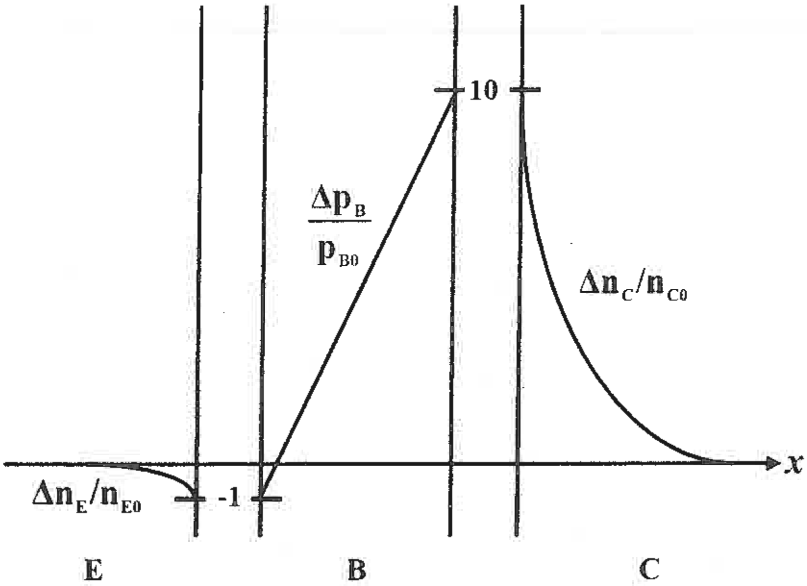
(a) The polarity of V_{EB}. (3%)

(b) The polarity of V_{CB}. (3%)

(c) The magnitude of V_{CB}. (3%)

(d) The biasing mode of this BJT. (3%)

(e) Repeat part (a) to (d) if this device is an NPN BJT. (3%)



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