EECS170A Fall 2011 **Midterm 1**

10/21/2011 4:00pm to 4:50pm
Professor Peter Burke

Name: Solution Grading Criteria

ID no.:_____

1	2	3	4	Total
/25	/25	/25	/25	/100

DO NOT BEGIN THE EXAM UNTIL YOU ARE TOLD TO DO SO.

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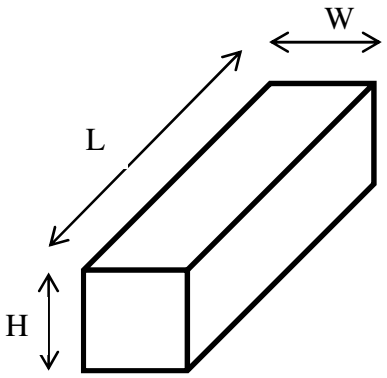
PROBLEM ONE: (25 points)

A Silicon bar at room temperature is doped with $N_A = 10^{17}$ cm^{-3} and $N_D = 0$.

Calculate the Resistance in (Ω) of the bar with L = 100μm and Height = Width = 1μm.



Solution:

$$R = \rho \frac{l}{A}$$ 8 pts for writing correct formula.

From the resistivity chart, $\rho \approx 0.2$ Ω-cm for $N_A = 10^{17}$ cm^{-3} 7 pts for correct approximation

Acceptable range (0.1 to 0.3)

$$R = 0.2\ \Omega\text{-cm}\frac{100\mu m}{(1\mu m)^2} = 200k\Omega$$ 10pts for correct set up calculation

Acceptable range (150k to 250k)

PROBLEM TWO(25 points):

From problem #1, Find $E_C - E_F$ and $E_F - E_V$. Sketch the Band Diagram and indicate your findings.

Solution:

$$E_i - E_F = kT \ln(N_A / n_i) = 0.0259 \ln(10^7) = 0.417eV$$

2pts for correct equation

2pts for correct natural log approximation

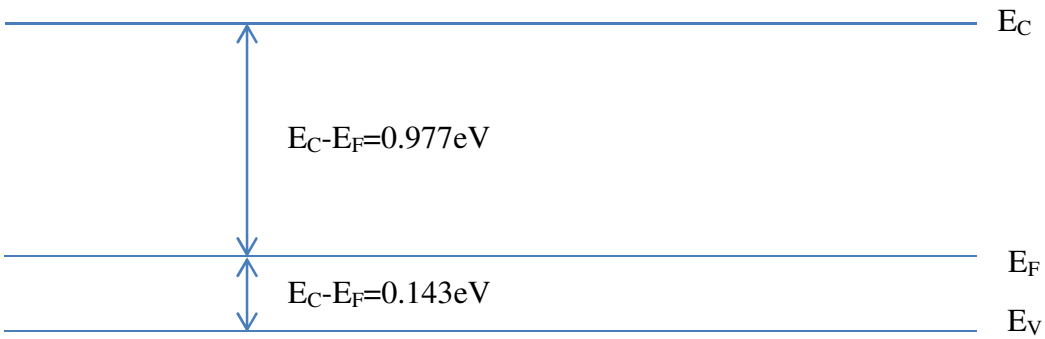
2pts for correct answer : Acceptable range (0.4 to 0.5)

$$E_c - E_F = Eg/2 + (E_i - E_F) = 0.56 + 0.417 = 0.977eV$$

6pts for correct $E_C - E_F$ Acceptable range (0.85 to 0.99)

$$E_F - E_V = Eg - (E_c - E_F) = 1.12eV - 0.977eV = 0.143eV$$

6pts for correct $E_F - E_V$ Acceptable range (0.1 to 0.25)



3.5 pts for correct $E_C - E_F$ Drawing. Acceptable range (0.85 to 0.99)

3.5 pts for correct $E_F - E_V$ Drawing. Acceptable range (0.1 to 0.25)

PROBLEM THREE(25 points):

Given Silicon at room temperature with $E_C - E_F = 0.3eV$ and same geometry as problem #1. Calculate:

a) the electron concentration (n in cm^{-3})
b) hole concentration (p in cm^{-3})
c) resistivity (ρ in Ω-cm)
d) majority carrier mobility (μ in $cm^2/V\text{-}s$)
e) dopant concentration (in cm^{-3})

Solution:

a)

$$E_C - E_F = 0.3eV$$
$$E_F - E_i = 0.56eV - 0.3eV = 0.26eV$$
$$E_F - E_i = kT\ln(n/ni) = 0.0259\ln(n/10^{10})$$

5pts for setting for $E_F - E_i$ equation

$$n = 2.289*10^{14}\,cm^{-3}$$

Acceptable range (10^{14} - $9.9*10^{14}$)

b)

$$p = n_i^{\,2}/n = 4.368*10^{5}\,cm^{-3}$$

5pts for correct answer.

Acceptable range (10^4 - $9.9*10^4$)

c), d), e)

With n >> p, Nd ≈ n = $2.289*10^{14}\,cm^{-3}$ 5pts for correct assumption.

$\mu_n \approx 1500cm^2/V*s$ from the mobility chart. 5pts for correct approximation.

Acceptable range (1000-2000)

$$\rho = \frac{1}{q\mu_n N_D} = \frac{1}{1.6*10^{-19}*1500*2.289*10^{14}} = 18.2\ \Omega\text{-cm}$$

5pts for correct resistivity

Acceptable range (10-30)

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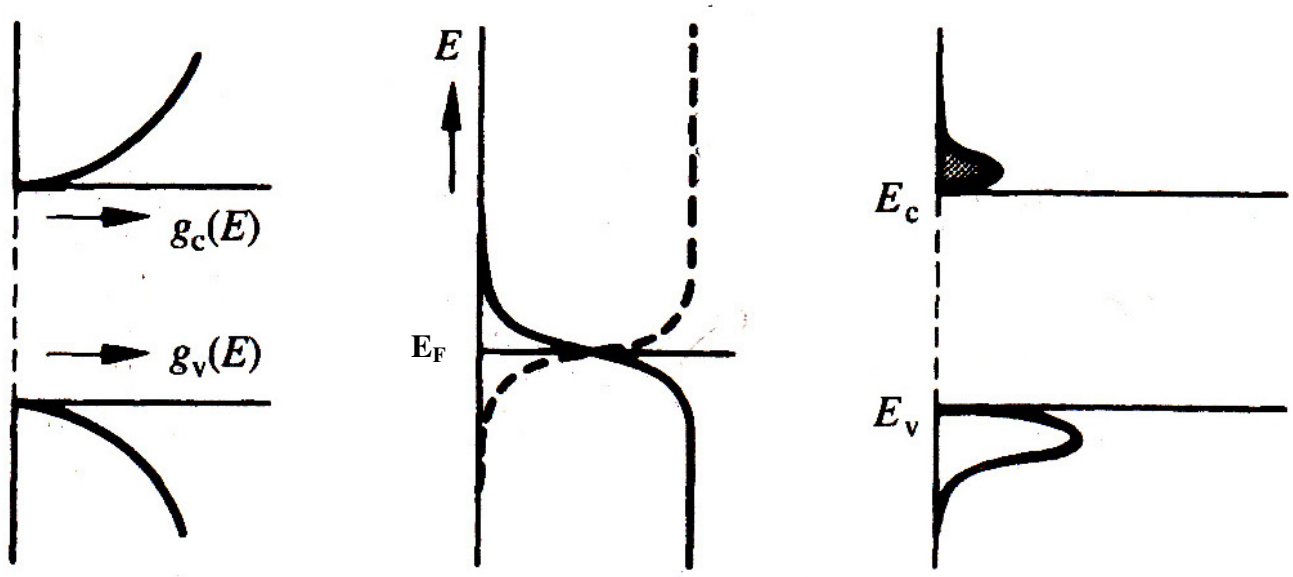
PROBLEM FOUR(25 points):

Sketch the probability distribution function f(E) for electrons, 1-f(E) for holes, density of states $g_c(E)$ for electrons, $g_v(E)$ for holes, and the energy distribution of carriers $f(E)*g_c(E)$ for electrons and $g_v(E)*(1-f(E))$ for holes problem #1.

Density of States | **Probability distribution function** | **Energy distribution of carriers**



5pts for correct drawing of $g_c(E)$ for electrons.

5pts for correct drawing of $g_v(E)$ for holes.

5pts for correct drawing of f(E) and 1-f(E) note*(if you did not draw 1-f(E), at least make some sort of mention of it on the plot for answer to be accepted)

5pts for correct drawing of $f(E)*g_c(E)$

5pts for correct drawing of $g_v(E)*(1-f(E))$