ECE 340 Midterm 2
Review Questions

Sanat, Alex

Fall 2019

1 P-N Junctions in Equilibrium

Table 1: Parameters of P-N Junction

Parameter	Value
T	300 K
n_i	2×10^{13} cm^{-3}
ϵ_r	20
N_D on n-side	4×10^{18} cm^{-3}
N_A on p-side	1×10^{18} cm^{-3}

This problem asks about a germanium ($E_G = 0.66$ eV) pn junction in equilibrium with the parameters from Table 1. Assume the junction occurs at $x = 0$, with the p region existing in $x < 0$ and the n region existing in $x > 0$.[1]

1.1 Determine the built-in potential, V_0, given that $kT \approx 0.03$ eV and $ln(10) \approx 2$.

1.2 Determine the depletion width, W, given that $\frac{\epsilon}{q} \approx 1 \times 10^7$ V^{-1} cm^{-1} and $\sqrt{15} \approx 4$.

[1] All values are rounded to one significant figure. Use the rounded values in your calculations.

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1.3 Sketch a quantitative band diagram, assuming $ln(2) \approx 1$. Label **all** relevant distances on the x and y axes.

1.4 Plot the corresponding charge diagram on the same horizontal scale and label minima and maxima.

1.5 Plot the electric field vs position on the same horizontal scale and label minima and maxima.

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1.6 For each of the following, list whether each of the built-in potential and depletion width would decrease, increase, or stay the same. Explain why.

1.6.1 The temperature is decreased to 150 K.

1.6.2 N_D on the n side is decreased to 3×10^{18} cm^{-3}.

1.6.3 The material is replaced with silicon ($E_G = 1.1$ eV, $\epsilon_r \approx 10$).

2 P-N Junctions Under Bias

2.1 Sketch a qualitative energy band diagram, including quasi-fermi levels, for the previous pn junction under (a) forward bias and (b) reverse bias.

2.2 Plot δp_n for $x > x_n$, the excess hole concentration on the n side of the junction.

2.3 Add a second trace to 2.2 for the case when N_D was decreased.

2.4 Explain the method of avalanche breakdown and the conditions under which it occurs. Additionally, explain why it is useful in creating photodetectors.

2.5 Explain the method of zener breakdown and the conditions under which it occurs.

3 Metal-Semiconductor Junctions

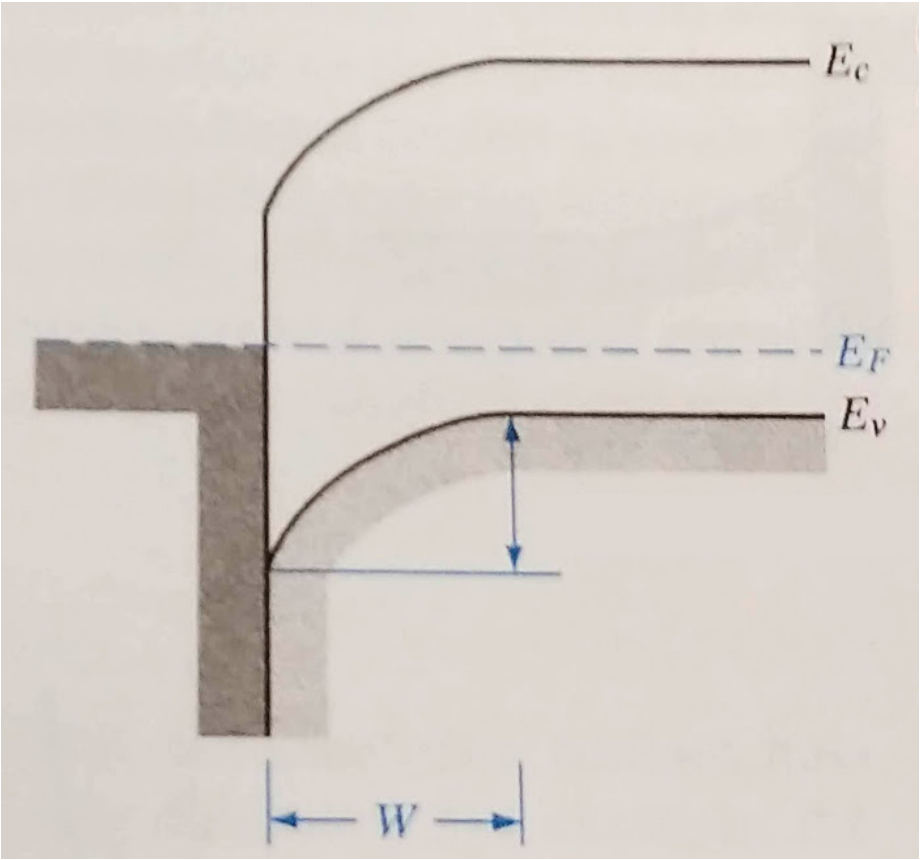

Figure 1: Metal-Semiconductor Band Diagram

3.1 Is the semiconductor p-type, n-type, or intrinsic?

3.2 Is the work function of the semiconductor or metal greater?

3.3 Is the junction rectifying or ohmic?

4 Optoelectronics

4.1 Sketch the I-V characteristic of an illuminated pn junction with light of energy $h\nu > E_G$.

4.2 Mark the quadrants where each of photodetectors, solar cells, and LEDs operate.

4.3 What are the conditions for lasing, and how does the emission change as lasing begins?