Problem 1 [13 points] One-sided pn Junction

The excess hole concentration within the quasi-neutral n-type region of a silicon p’n step junction of area \( A = 1\text{mm} \times 1\text{mm} \) maintained at \( T = 300\text{K} \) is plotted on a linear scale below. The hole lifetime \( \tau_p = 10^{-6} \text{s} \).

(a) Calculate the minority-carrier charge stored in this diode, \( Q_p \). [3 pts]

(b) Calculate the diode current, \( I \). [3 pts]

(c) Estimate the small-signal capacitance, \( C \), of this junction. [3 pts]

\[
\frac{1}{0.026} \approx 40
\]

(d) Show on the plot above how \( p_n(x) \) would change if \( \tau_p \) were to be decreased by a factor of 4. [2 pts]

Qualitatively, how would the diode turn-off transient response change? Explain briefly. [2 pts]
Problem 2 [5 points] Optoelectronic Diodes
Circle the correct choices in the sentences below.

(a) Light is generated in a [light-emitting diode or photodiode] when it is operated under [forward or reverse] bias due to [generation or recombination] within the [depletion region or quasi-neutral regions]. [2 pts]

(b) The amount of electric power generated by a solar cell [increases or decreases] with an increase in temperature (e.g. in the range from 300K to 400K). [1 pt]

Justify your answer. [2 pts]

Problem 3 [7 points] MOS Capacitor
(a) Identify the bias condition (accumulation, depletion, or inversion) for the MOS energy-band diagrams below [3 pts]

(b) Consider a MOS capacitor with 3.45 nm = 3.45×10⁻⁷ cm SiO₂ and p-type Si with \(N_A = 10^{17} \text{ cm}^{-3}\) maintained at 300K. The flatband voltage \(V_{FB} = -0.8\text{V}\). **Calculate the threshold voltage, \(V_T\).** [4 pts]
(Note: The permittivity of SiO₂ is 3.45×10⁻¹³ F/cm.)