230A Problem:

To answer the following problem, use the following properties for a “hypothetical semiconductor”.

\( E_g = 1.0 \text{ eV} \)  assume \( E_V = 0 \text{ eV} \) as the reference

\( N_C = N_V = 1 \times 10^{18} \text{ cm}^{-3} \)

\( C_{pe} = C_{ph} = 10^{-9} \text{ cm}^3\text{s}^{-1} \)

\( \mu_n \) (electron mobility) = 1500 \( \text{cm}^2\text{V}^{-1}\text{s}^{-1} \)

\( \mu_p \) (hole mobility) = 200 \( \text{cm}^2\text{V}^{-1}\text{s}^{-1} \)

\( T = 300 \text{ (K)} \), \( kT = 0.0259 \text{ (eV)} \)

(a) Calculate the intrinsic carrier concentration \( n_i \) at room temperature (300K).
(b) Calculate the electron and hole diffusivity.
(c) Assuming \( E_d \) (donor state energy) is 0.01 eV below \( E_C \), \( N_d = 10^{17} \text{ cm}^{-3} \), \( T = 300\text{K} \), calculate the Fermi energy.
(d) If the material in (c) has a trap density of \( N_t = 1 \times 10^{15} \text{ cm}^{-3} \), calculate the minority carrier lifetime.
(e) Find the minority carrier diffusion length of material in (d).

230B Problem:

An n-channel MOSFET has a 10 nm thick gate oxide and uniform p-type body doping of \( 10^{17} \text{ cm}^{-3} \). The device is 10 \( \mu \text{m} \) wide and the channel length is 1 \( \mu \text{m} \). Assume Si, room temperature, and complete ionization.

(a) What is the inverse slope of the log subthreshold current vs. \( V_g \) curve?
(b) For a gate bias such that \( V_g-V_t=2.5 \text{ V} \) where the mobility is 400 \( \text{cm}^2\text{V}^{-1}\text{s}^{-1} \), what is the MOSFET channel conductance, \( \frac{dI_{ds}}{dV_{ds}} \), at low drain bias voltages?
(c) How short can the channel length be reduced before onset of severe short-channel effects?