Consider the same problem as in HW 1, namely a channel with a density of states given by,
\[ D(E) = D_0 \vartheta(E) \], where \( \vartheta \) represents the unit step function. The equilibrium electrochemical potential \( \mu = 0.1 \text{ eV} \) and \( k_B T_1 = k_B T_2 = 0.025 \text{ eV} \). Assume the escape rates \( \gamma_1 \) and \( \gamma_2 \) to both be equal to 10 meV, and the density of states (for \( E > 0 \)) \( D_0 \) to be 0.1 / eV.

Problems 1 and 2 below require a computer evaluation of the current expression discussed in class:

\[
I = \frac{q}{h} \int_{-\infty}^{\infty} dE (E-U) \frac{\gamma_1 \gamma_2}{\gamma_1 + \gamma_2} \left[ f_1(E) - f_2(E) \right] \tag{1}
\]

but Problem 2 also requires an additional self-consistent evaluation of \( U \) from the equations

\[
N = \int_{-\infty}^{\infty} dE (E-U) \frac{\gamma_1 f_1(E) + \gamma_2 f_2(E)}{\gamma_1 + \gamma_2} \tag{2}
\]

\[ \text{and} \quad U = U_e + U_0 (N - N_{eq}) \tag{3} \]
Problem 1: Calculate the current (I) versus drain voltage ($V_D$) for $-0.4V < V_D < +0.4V$ assuming $U_0 = 0$, and

(a) $U_L = 0.5 \times (U_{source} + U_{drain})$,
(b) $U_L = U_{source}$,
(c) $U_L = U_{drain}$.

Note that $U_{drain} = U_{source} - qV_D$, $\mu_1 = \mu + U_{source}$, $\mu_2 = \mu + U_{drain}$.

Problem 2: Calculate the current (I) versus drain voltage ($V_D$) for $-0.4V < V_D < +0.4V$ assuming $U_0 = 5$ eV and $U_L = U_{source}$.

Problem 3: Electrons in a semiconductor obey a modified Schrödinger equation which in one dimension has the form

$$i\hbar \frac{\partial \psi}{\partial t} = -\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} + \alpha \frac{\partial^4 \psi}{\partial x^4}$$

where $\alpha$ and $m$ are constants. Assume a solution of the form ($\psi_0$ being a constant)

$$\psi(x,t) = \psi_0 e^{ikx} e^{-iEt/\hbar}$$

to find the dispersion relation $E(k)$. 