Problem 1. (25 pts.) The charge density in a semiconductor junction (semiconductor permittivity = \( \varepsilon \)) varies only in the \( x \) direction and is given by \( \rho_v = 6\varepsilon x \) C/m\(^3\) over the range \( (-x_o \leq x \leq x_o) \). The boundary conditions for the semiconductor junction are \( E_x(-x_o) = E_x(x_o) = 0 \) V/m and \( V(0) = 0 \) V. Determine
(a.) the potential as a function of \( x \) within the junction \( (-x_o \leq x \leq x_o) \).
(b.) the vector electric field as a function of \( x \) within the junction \( (-x_o \leq x \leq x_o) \).
(c.) the potential difference across the junction from \( x_o \) to \(-x_o\).

Problem 2. (20pts.) A square grid with \( \Delta x = \Delta y = 1 \) cm is shown for the 2-D conductor system given below. A finite-difference solution is sought for the potential throughout the region between the conductors which is characterized by \( \rho_v = 10x^2y^2 \) C/m\(^3\) and \( \varepsilon = \varepsilon \).
(a.) Using symmetry to simplify the solution, write the number of finite-difference equations necessary to solve for the potential at all free nodes \( \{V_i^{(k)}\} \) where \( i \) is the grid point index and \( k \) is the iteration number.
(b.) Determine the free node voltages for the minimum number of equations in (a.) for the first three iterations assuming an initial guess of zero for all free node voltages.

Problem 3. (10 pts) A DUT generates noise currents at a level of 21 dB\(\mu\)A (average) at 30 MHz. Determine if the DUT passes or fails conducted emissions compliance (and by how much) for
(a.) Class A operation.
(b.) Class B operation.

Problem 4. (20 pts) A product is tested for radiated emissions compliance at \( f = 550 \) MHz where the distance between the DUT and the measurement antenna is 14 ft. The antenna factor of the measurement antenna is 18 dB and is connected to the spectrum analyzer by 10 ft. of coaxial cable (loss of 8.9 dB/100 ft at 500 MHz). The voltage measured by the spectrum analyzer is 34 dB\(\mu\)V. Determine
(a.) the cable gain.
(b.) the magnitude of the voltage (dB\(\mu\)V) at the measurement antenna terminals.
(c.) the electric field magnitude (dB\(\mu\)V/m) at the measurement antenna.
(d.) if the product passes or fails FCC Class B compliance and by how much.

Problem 5. (25 pts.) The radiated emission from a conductor pair (length 0.3 m, separation = 4 mm) is measured at 150 MHz at a distance of 3.2 m in the direction of maximum radiation. The measurement antenna has an antenna factor of 14 dB and connected to a spectrum analyzer by 20 ft. of coaxial cable (loss of 6.2 dB/100 ft at 150 MHz). The spectrum analyzer reads a voltage of 63 dB\(\mu\)V. Determine the magnitude of the current producing this emission assuming
(a.) the current is a differential-mode current.
(b.) the current is a common-mode current.
1. (a) \( \frac{d^2 V}{dx^2} = -\frac{6V}{e_0} \Rightarrow \frac{d^2 V}{dx^2} = -6 \frac{V}{x} = -6x, \frac{dV}{dx} = -6 \frac{x^2}{2} + C_1 = -3x^2 + C_1, V(x) = -3x^2 + C_1, C_1 = 3x_0^2, V(0) = C_2 = 0 \)

(b) \( E_x(x) = 3x^2 - 3x_0^2 \frac{V}{m} \)

(c) \( V(x_o) - V(-x_o) = -3x_0^3 + 3x_0^2 - (x_0^3 - 3x_0^2) = 4x_0^3 \frac{V}{m} \)

2. (a) \( V_1 = V_5 = V_2 = V_6 = V_2 = V_0 = V_0 = V_1 = V_2 = V_3 = V_5, V_2 = V_8 = V_8 = V_1 \)

\( V_1 = \frac{1}{4} [V_{4+3} + V_{-1-1} + V_{4+1} + V_1] + \frac{1}{4} [V_{6+1} + V_{6-1} + V_{6+1} + V_6] \)

\( \frac{1}{4} \left( V_{4+3} + V_{6+1} + V_{4+1} + V_1 \right)^2 + \frac{1}{4} \left( V_{6+1} + V_{6-1} + V_{6+1} + V_6 \right)^2 \)

(b) \( V_1^{(1)} = 24.52, V_2^{(1)} = 11.13, V_3^{(1)} = 10 \)

3. \( 21 \text{dBm} = \frac{10^{21/20}}{10^{21/20}} = 11.22 \mu A \)

\( V = IR = (11.22 \mu A)(50 \Omega) = 561 \mu V (54.98 \text{ dB} \mu V) \)

(a) Class A (50 mHz) \( \Rightarrow 60 \text{ dB} \mu V \) \( \text{PASSES BY 5.02 dB} \)

(b) Class B (50 mHz) \( \Rightarrow 50 \text{ dB} \mu V \) \( \text{FAILS BY 4.98 dB} \)

4. (a) \( [-8.9 \text{ dB }/100^\circ F] \times 10^4 = -0.89 \text{ dB} \)

(b) \( V_{out} = 34 \text{ dB} \mu V \), \( V_{in} = V_{out} - \text{CABLE GAIN}_{db} = 34 + 0.89 = 34.89 \text{ dB} \mu V \)

(c) \( E_{inc} = V_{ant} + 0 \text{ dB} = 34.89 + 12 = 52.89 \text{ dB} \mu V/m \)

(d) \( E(R) = 46 \text{ dB} \mu V/m \) \( R = 3m \), \( E(R') = E(R) + 20 \log_{10} \left( \frac{R}{R'} \right) \)

\( E(R') = 46 + 20 \log_{10} \left( \frac{3m}{1m} \right) = 42.94 \text{ dB} \) \( \text{FAILS BY 9.95 dB} \)

5. (a) \( V_{in} = V_{out} - \text{CABLE GAIN} = 63 + \frac{6.2}{130 + 4} = 64.24 \text{ dB} \mu V \)

\( E_{inc} = V_{ant} + 0 \text{ dB} = 64.24 + 14 = 78.24 \text{ dB} \mu V/m (8166 \mu V/m) \)

(a) \( I_0 = I_{E_{thr}}|d|/(1.316 \times 10^{-8} \mu F^2 L) = 73.5 \mu A \)

(b) \( I_c = I_{E_{thr}}|d|/(1.257 \mu F L) = 462 \mu A \)