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EE 239

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Problem Set 10 Solution

Problem 11.5 $\lambda_i = \frac{1}{330\,p}\ \text{cm} = 1\ \text{cm}$

$h_\ell = 0.86/(3 + d/2\lambda_i)^{1/2} = 0.326$, $d_{eff} = d/2h_\ell = 12.3\ \text{cm}$

$n_g d_{eff} = 1.21 \times 10^{15}\ \text{cm}^{-2} = 1.21 \times 10^{19}\ \text{m}^{-2}$ Fig 10.1 $\Rightarrow T_e = 3.3\ \text{V}$

$u_B = 2.8 \times 10^5\ \text{cm/s}$. Fig 3.17 $\Rightarrow \mathcal{E}_c = 55\ \text{V}$; $\mathcal{E}_c' = 23.6\ \text{V}$

Fig 3.16 $\Rightarrow \nu_m = K_{el} n_g = 8.9 \times 10^6\ \text{s}^{-1}$

From (11.2.33a), $\bar{S}_{ohm} = 0.132\, V_1^{1/2}\ \text{W/m}^2$

From (11.2.34), $\bar{S}_{stoc} = 0.125\, V_1\ \text{W/m}^2$

Using (11.2.38)

$$2000 = (0.132\, V_1^{1/2} + 0.25\, V_1)\left(1 + \frac{0.83\, V_1}{78.6}\right)$$

$\Rightarrow V_1 = 817\ \text{V}$; $V_{rf} = 1634\ \text{V}$, $\mathcal{E}_i = 0.83 V_1 = 678\ \text{V}$

From (11.2.37), $n_s = 2.9 \times 10^9\ \text{cm}^{-3}$; $n_0 = 8.0 \times 10^9\ \text{cm}^{-3}$,

and $\bar{J}_i = 0.13\ \text{mA/cm}^2$; from (11.2.15), $s_m = 1.45\ \text{cm}$

From (11.2.21), $J_1 = 7.5\ \text{mA/cm}^2$

Problem 11.6 (a) Guess $s_m = 1\ \text{cm}$ so $d = 0.08\ \text{m}$

At 30 mTorr, $\lambda_i = 0.1\ \text{cm} = 10^{-3}\ \text{m}$

$h_\ell = 0.131$; then $d_{eff} = 0.305\ \text{m}$

Then $n_g d_{eff} = 3.05 \times 10^{20}\ \text{m}^{-2}$

From Fig 10.1, $T_e = 2.1\ \text{V}$

From Fig 3.17, $\mathcal{E}_c = 58\ \text{V}$, $u_B = 2.2 \times 10^3\ \text{m/s}$

(b) $V_1 = 400\ V$ and $\bar{V} = 0.78 V_1 = 312\ V$

$\mathcal{E}_T = \mathcal{E}_i + \mathcal{E}_e' + \mathcal{E}_c = 312 + 7.2 T_e + 58 = 385\ V$

Fig. 3.16 $\Rightarrow$ $\nu_m = K_{elas} n_g = 7 \times 10^{-14} \times 10^{21} = 7 \times 10^{7}\ s^{-1}$

(11.2.33a) $\Rightarrow$ $\bar{S}_{ohm} = 0.336 V_1^{1/2} = 6.73\ W/m^2$

(11.2.59) $\Rightarrow$ $\bar{S}_{stoc} = 0.136 V_1 = 54.3\ W/m^2$

(11.2.36) $\Rightarrow$ $115 = 2e u_B \cdot 73.1 \cdot n_s$

$n_s = 2.24 \times 10^{15}\ m^{-3}$; $\Gamma_i = n_s u_B = 4.9 \times 10^{18}\ m^{-2} s^{-1}$

(c) $\bar{V} = 312\ V$ as in (b). From (11.2.54) with $\bar{J}_i = e\Gamma_i = 0.788\ A/m^2$, we find $s_m = 8.76 \times 10^{-3}\ m$. Then using (11.2.57),

$\mathcal{E}_{ic} = 22.1\ V$

(d) Done in (c)

(e) From (11.2.37), $S_{abs} = 607\ W/m^2$

(f) From (11.2.55), $J_1 = 52.4\ A/m^2$

Problem 3

(a) From (11.2.55), $C_D = \dfrac{(1.52)(8.85\times10^{-12})(0.1)}{0.009}$

$C_D = 149.5$ pF //

Use $P_{abs} = \frac{1}{2} R_D I_{rf}^2$ to find R_D

$R_D = \dfrac{(2)(60)}{5^2} = 4.8\ \Omega$ //

(b) From (11.8.10)

$X_M = [(4.8)(50) - 4.8^2]^{1/2} - \left[\dfrac{1}{85.2\times10^6 \times 149.5\times10^{-12}}\right]$

$= 93.2\ \Omega$ //

$L_M = X_M/\omega = 1.09\ \mu H$ //

From (11.8.11)

$B_M = \left(\dfrac{1}{R_T R_D} - \dfrac{1}{R_T^2}\right)^{1/2} = 6.14\times10^{-2}$ S //

$C_M = B_M/\omega = 720$ pF //

So we have