CHEMICAL ENGINEERING DEPARTMENT
ChE 234, Spring, 2004

Homework Assignment No. 6

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Assigned May 25, 2004 Due June 1,2004

1. [*15*] An ICP has a flat, insulating wall outside of which an antenna applies an RF field at 13.56 MHz. If the 3-eV argon plasma is 1% ionized and has density $n = 10^{11}$ cm^{-3}, what is the skin depth δ_s for the RF field including the effect of electron-neutral collisions? [Hint: Before solving the complex equation, check if the Taylor expansion is valid. If it is, you can use it.]

2. [*15*] You are to design a matching circuit for a 2.0-MHz RF plasma source. The antenna has an inductance of 12 μH (microhenries), and the plasma is expected to present a resistance of about 1.5Ω, with a negligible reactance compared with that of the antenna. The RF power supply has an output impedance of 50Ω, and the coaxial cables also have 50Ω characteristic impedance. Using the formulas given in the text, calculate the capacitances C_1 and C_2 [in pF (picofarads)] around which the "alternate" circuit should be designed. [Note: C_1 is the same as the loading capaciutor C_L, and C_2 is the tuning capacitor C_T. Work in dimensionless units; then convert back to real units.]

3. [*15*] Calculate the parallel wavelength of a 27.12-MHz helicon wave in a 5-cm diam cylinder if $\mathbf{B}_0$ = 800G and $n = 10^{13}$ cm^{-3}. [Note: You do not have to know about Bessel functions if you understand the explanation in the text. The equations there are in MKS. You will need to solve a quadratic equation for k^2.]

4. [*15*] The density in a uniform, 10-cm thick slab of plasma is measured with a 65-GHz, double-pass microwave interferometer. If the measured phase shift is $\Delta\phi = 30°$, what is the density? [Hint: Assume that the Taylor expansion is valid; then justify it *a posteriori.* Easiest to use CGS.]

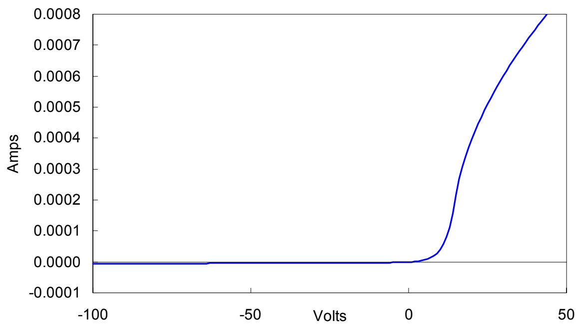
5. [*15*] You are to design a magnetic probe to measure a magnetic field expected to be $B = B_0 \sin\omega t$, where B_0 = 10G and $\omega/2\pi$ = 0.4 MHz. Each turn of the coil is a circle 5 mm in *diameter*. How many turns are necessary to get a peak voltage of 1V? [Hint: The equations are in MKS. Assume $B = B_0 \sin \omega t$.]

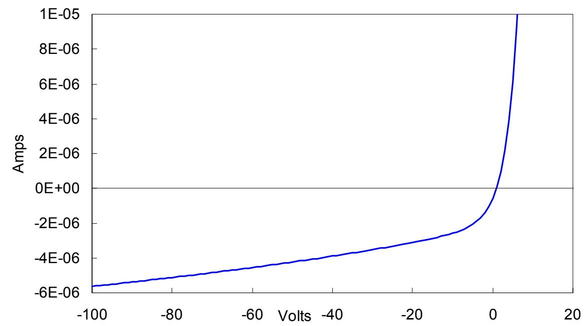
6. [*25*] The $I - V$ curve for a 0.15 mm diam, 1 cm long Langmuir probe is shown below, together with an enlarged view of the ion saturation current. The data for these curves are given in the table.

a) Using Eq. (16) of the text for the OML (Orbital Motion Limited) theory, find the plasma density by fitting a straight line to a plot of I^2 vs. V_p.

b) Subtract the theoretical ion current from the straight line from the total (negative) current to obtain the electron current I_e. Plot I_e vs. V_p on a semi-log scale and fit a straight line to obtain KT_e for this plasma. [Note: I can e-mail you an Excel file or a comma-separated file (.csv) containing the data so that you don't have to type it in.]

[Hint: To fit a straight line, you can use the SLOPE and INTERCEPT functions in Excel if you have the Analysis Toolpak installed. Otherwise, you can find M and B of the line $y = Mx + B$ by hand on a graph. Before making the semilog plot of I_e, change to the magnitude of I_e so that it never goes negative. Then add the ions from the square root of the straight line fit of I^2. After you fit a line to $\ln(I_e)$, you have to change back to I_e to get the slope, and thus KT_e.]





Vp	Ie(A)		Vp	Ie(A)
-100	-5.6E-06		0	-5.6E-07
-95	-5.5E-06		1	8.9E-08
-90	-5.4E-06		2	9.7E-07
-85	-5.3E-06		3	2.2E-06
-80	-5.1E-06		4	3.8E-06
-75	-5.0E-06		5	6.1E-06
-70	-4.8E-06		6	9.3E-06
-65	-4.7E-06		7	1.4E-05
-60	-4.5E-06		8	2.0E-05
-55	-4.4E-06		9	2.8E-05
-50	-4.2E-06		10	4.0E-05
-45	-4.1E-06		11	5.7E-05
-40	-3.9E-06		12	7.9E-05
-35	-3.7E-06		13	1.1E-04
-30	-3.5E-06		14	1.6E-04
-25	-3.3E-06		15	2.2E-04
-20	-3.1E-06		15	2.2E-04
-15	-2.9E-06		16	2.7E-04
-10	-2.6E-06		17	3.1E-04
-9	-2.5E-06		18	3.4E-04
-8	-2.4E-06		19	3.7E-04
-7	-2.3E-06		20	4.0E-04
-6	-2.2E-06		25	5.1E-04
-5	-2.1E-06		30	6.0E-04
-4	-1.9E-06		35	6.8E-04
-3	-1.7E-06		40	7.5E-04
-2	-1.4E-06		45	8.1E-04
-1	-1.0E-06		50	8.7E-04