Homework problems for normal conducting rf

Section 1

1.1 Imagine that the waveguide standard WR-97 existed. Sketch the dispersion curve. What is the cutoff frequency? What are the group and phase velocities at 1.2, 1.5, 2 and 10 times this frequency

1.2 What is the transit time factor for a cavity operating at 11.994 GHz which is one third of a wavelength long? At which phase should you inject to get maximum acceleration? To get zero acceleration? At which length would such a cavity not give any acceleration?

1.3 Plot the following disk loaded waveguide dispersion curves. What are the phase and group velocities of the 0,π/3,π/2,2π/3 and π modes? The cell length is 8.332 mm.

Iris diameter	6 mm	Iris diameter	3 mm
Phase [degrees]	Frequency [Hz]	Phase [degrees]	Frequency [Hz]
0	10530194428	0	11789563652
10	10544884522	10	11791704341
20	10588438665	20	11798147902
30	10659540055	30	11808517016
40	10756048590	40	11822597481
50	10874671328	50	11839943852
60	11012127448	60	11860049565
70	11163734072	70	11882251163
80	11325437241	80	11905853130
90	11492412104	90	11930207198
100	11658954444	100	11954538315
110	11820739142	110	11978108377
120	11972028973	120	12000204306
130	12109341843	130	12020159331
140	12228070989	140	12037372687
150	12324701847	150	12051327206
160	12396260365	160	12062294745
170	12440130247	170	12068960981
180	12454846032	180	12070540024

Section 2

2.1 An 11.994 GHz cavity 8.332 mm long has an R/Q=139 Ω. A 1 nC charge traverses the cavity. How much energy is deposited in the fundamental mode? What accelerating gradient does this correspond to?

2.2 The middle cell of a CLIC accelerating structure has 2pi/3 phase advance, a Q of 6200, a shunt impedance of 100 Mohm/m and a group velocity vg/c=1%. What is the accelerating gradient in the cell for a power flow of 50 MW? What is the stored energy per meter and per cell?

2.3 Assume that a travelling wave accelerating structure is built out of 30 of such cells. What is the accelerating gradient as a function of distance for an input power of 50 MW? What is the average accelerating gradient over the whole structure? What is the output power from the structure?

2.4 What current is required to obtain full beam loading in the structure? Plot the gradient along the structure. What is the total voltage of the structure? What would be the rf to beam efficiency for that current? Do the analysis again for half that current. What do you conclude?

2.5 Let’s keep driving this structure with the I/2 current but make the structure longer and longer and longer. What happens?

2.6

OPTIONAL - Re-do the energy balance consistency check done on page 14 but for *arbitrary* injection phase.

2.7

OPTIONAL - Re-derive the differential equation for power flow on page 26 but expressed in terms of gradient. Solve the fields in a constant gradient structure, then compute the average gradient and rf-to-beam efficiency.

Section 5

5.1 A structure has a dipole mode frequency equal to 18 GHz with amplitude 1. Plot the long range wake. How could you make a structure one half has a dipole wake of 18 GHz and the other half has a dipole wake of 19 GHz? What would the long range wake be? Where would you put a second bunch in a train? What about the third? How would it change if you doubled the bandwidth (ie half at 18 GHz and the other at 20 GHz)? Now let's go back to 1 GHz bandwidth. What happens to the wake if you make the structure out of 4 and 8 geometries? Compare the detuned-wake to the damped cell with a Q of 20. What differences do you see and why? Where would you put following bunches? Restricting yourself to 1 GHz bandwidth and 16 frequencies, mess around with something and try to improve the wake in different ways.

Section 6

6.1 The following two set of current vs. voltage data were taken in the CERN dc spark set-up. What was the field enhancement factor β and the emission area in each case.

Case 1 Gap distance 29.7 microns Case 2 Gap distance 18.8 microns

Voltage V [V]	Current I [A]	Voltage V [V]	Current I [A]
3100	1.22E-11	600	1.53E-11
3150	1.66E-11	625	5.07E-11
3200	2.07E-11	650	1.47E-10
3250	2.68E-11	675	3.96E-10
3300	2.84E-11	700	8.57E-10
3350	3.83E-11	725	1.69E-09
3400	5.04E-11	749	3.42E-09
3450	5.77E-11	774	5.60E-09
3500	6.78E-11		
3550	8.65E-11		
3600	1.03E-10		
3650	1.19E-10		
3700	1.38E-10		
3750	1.28E-10		
3800	1.50E-10		
3850	2.12E-10		
3900	2.46E-10		
3950	2.79E-10		
4000	3.21E-10		
4050	3.80E-10		
4100	4.53E-10		
4150	5.14E-10		
4200	5.90E-10		
4250	7.00E-10		
4300	8.59E-10		
4350	1.06E-09		