Homework Set #3

(Homework Problems for Chapter 2)

1. Consider FODO lattice discussed in the class. Use the properties of the envelope function β in the free space (Eq. (2.32)), at thin lenses (Eq. (2.33)), and the periodicity and the symmetry of the problem.

   a. Show that the maximum and the minimum envelope functions are given by:

   $$\beta_{\substack{max \\ min}} = 2F\sqrt{\frac{1 \pm d/2F}{1 \mp d/2F}}$$

   b. Indicate (you need not do the actual calculation) how you could prove that the phase advance per period μ is given by:

   $$\sin\frac{\mu}{2} = \frac{d}{2F}$$

2. The shunt impedance for NLC X-band structure is $R_a/L = 90\ M\Omega/m$. Assuming the linac operates at the accelerating gradient of 40 MV/m let us consider the power dissipated in the copper structure for a 500 GeV (CM) collider. What is the total power necessary if the collider operates in the CW mode? How does it compare with the beam power? What is the average power necessary if the rf pulse is 0.4 μsec long and repeated at 120 Hz?

   As for the TESLA, assume that the shunt impedance is 10^6 times larger than the NLC. What is the power dissipated at 2K (liquid He temperature) if accelerating gradient is 25 MV/m? Due to the Carnot efficiency and other technical efficiency the necessary refrigerator power at the room temperature is about 10^3 times that dissipated at 2K. If TESLA is operated in CW, what is the refrigerator power?

3. Consider an electron storage ring with parameters (Advanced Light Source):

   Electron energy = 1.5 GeV, Circumference = 196.8m, rf frequency = 500 MHz, bending radius (ρ) = 4.01m, momentum compaction (α_p) = 1.43×10^{-3}, peak rf voltage V = 1.5MV

   a. Using the formula in Steve Holme's lecture, find the energy loss per turn due to the synchrotron radiation.
   b. What is the synchronous phase ϕ_s?
   c. Compute the synchrotron frequency Ω_s.
   d. Find the damping time (τ_D).