

**Homework Set #8**  
**(due: Wednesday, March 12, 2003)**

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

Electron energy = 1.5 GeV, Circumference = 196.8 m, rf frequency = 500 MHz, bending radius ( $\rho$ ) = 4.01 m, momentum compaction ( $\alpha_p$ ) =  $1.43 \times 10^{-3}$ , peak rf voltage  $V = 1.5$  MV.

- What is the energy loss per turn due to the synchrotron radiation.
  - What is the synchronous phase  $\phi_s$ ?
  - Compute the synchrotron frequency  $\Omega_s$ .
  - Find the damping time ( $\tau_y$ ).
2. In a high energy circular electron accelerator the economics is dominated by synchrotron radiation considerations. Consider a simplified model in which the construction cost is given by three terms:

$$\text{Cost} = \alpha + \beta\rho + \gamma W$$

Where  $\alpha$ ,  $\beta$ , and  $\gamma$  are constants and  $\rho$  is the bending radius in the accelerator and  $W$  is the synchrotron radiation energy loss per turn. ( $\alpha$  represents fixed costs that don't depend on the energy or size of the accelerator, for example, injection systems or office buildings;  $\beta\rho$  represents costs that scale linearly with the size of the accelerator, for example, the tunnel; and  $\gamma W$  represents costs that scale linearly with the energy loss per turn, for example, the rf system.) Show that in this model the optimum radius from the cost perspective is proportional to  $E^2$ , the optimum magnetic field is proportional to  $1/E$ , and that for small fixed costs the optimum cost is proportional to  $E^2$ .

3. 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 50 MV/m let us consider the power dissipated in the copper structure for a (250 GeV + 250 GeV) collider. What is the total power necessary if the collider operates in the CW mode? How does it compare with the beam power (Homework Set #1, problem 2)? What is the average power necessary if the rf pulse is 0.4  $\mu$ sec long and repeated at 120 Hz? *(continued on next page)*

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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?