USPAS Graduate Accelerator Physics Homework 6

Due date: Tuesday January 24, 2017

1 C-M 9.1: Plane Wave Acceleration

(8 points): How strong must the electric field intensity of a *traveling plane wave* be to accelerate electrons with an energy gradient of 10 MeV/m? (Hint: Use the Poynting vector.)

2 C-M 9.2: RF Cavity Power Loss

(8 points): Show that the RF power loss in the conducting walls of a cavity is given by equation (9.16) in the text.

3 RF Bucket Height and Area

Using the RF hamiltonian derived in class and in the text (7.79) (ignoring the p_s term in 7.79 that does not contribute to the equations of motion) for synchronous phase ϕ_s=0,

$$H_2(\varphi, W) \approx \left(\frac{\omega_{\rm rf}^2 \eta_{\rm tr}}{2\beta^3 U_s c}\right) W^2 - \left(\frac{qV}{L\omega_{\rm rf}}\right) \cos\varphi$$

(a) (5 points) ...calculate the maximum bucket height $\hat{W}$ using the fact that $H_2(\varphi = \pi, W = 0) = H_2(\varphi = 0, W = \hat{W})$.

(b) (5 points) ...calculate the bucket area in (φ, W) space by setting the Hamiltonian to the constant found in the first part, solving for W as a function of H_2 and φ, and integrating from $\varphi = 0$ to π.

4 C-M 7.3: RHIC RF Calculations

(a) (3 points) Calculate the synchrotron tune for RHIC for fully stripped $^{1}97\mathrm{Au}^{79+}$ gold ions with $\gamma_{\rm inj} = 10.4$, $\gamma_{\rm tr} = 22.8$, $L = 3833.845$ m, $h = 360$, $\phi_s = 0°$, $mc^2 = 197 \times 0.93113$ GeV, $Z = 79$, $A = 197$ (Note typo in book!), and $V_{\rm rf} = 300$ kV.

(b) (3 points) What is the synchrotron frequency?

(c) (3 points) For synchronous phase $\phi_s = 5.5°$, how much energy does the synchronous particle gain per turn?

(d) (3 points) How long would it take to accelerate to $\gamma = 107.4$ (100 GeV/nucleon)?

(e) (4 points) Plot the synchrotron frequency as a function of energy. Be careful when crossing through $\gamma = \gamma_{\rm tr}$.