20 POINTS

PROBLEM SET 13

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PROBLEM 1

CONSIDER THE PARAMETERS FOR A PROTON STORAGE RING IN SNS): WHICH THERE IS A SINGLE CIRCULATING BUNCH:

$N_0 = 2 \times 10^{14}$ protons / bunch

$l_{b\,eff} \simeq 124$ m = effective bunch length

$r_{pipe} = 0.1$ m = pipe radius

$\beta = 0.875 = \frac{v_z}{c}$ (ion velocity)

a) WHAT IS THE SINGLE BUNCH BEAM INDUCED MULTIPACTING PARAMETER δ_s?

b) WHAT IS THE CHARACTERISTIC ENERGY GAIN PER ELECTRON?

c) ASSUME AN IONIZATION CROSS SECTION OF 10^{-22} m^2, AND A DESORPTION COEFFICIENT 4, AND A LINEAR PUMP RATE S OF 0.1 m^3 s^{-1} m^{-1}. WILL THE PRESSURE BE STABLE IN THIS MACHINE AGAINST RUNAWAY DESORPTION? (Assume the beam fills the ring for making your estimate.)

d) Assume that $r_{b0} = 0.01$ m. ESTIMATE THE ELECTRON oscillation frequency in the field of the ion beam.

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(20 POINTS)

② Consider the effects of Coulomb collisions for a beam with an initial temperature $T_{\perp 0} \neq T_{\parallel 0}$. Assume τ = const and that

$$\frac{dT_\perp}{dt} = -\frac{1}{2}\frac{dT_\parallel}{dt} = \frac{-(T_\perp - T_\parallel)}{\tau}$$

Show that for initial values $T_\perp = T_{\perp 0}$ and $T_\parallel = T_{\parallel 0}$, that the general solution (when τ is assumed constant) is:

$$T_\parallel = A - \frac{2}{3} B \exp[-\alpha t]$$

$$\& \quad T_\perp = A + \frac{1}{3} B \exp[-\alpha t]$$

Calculate A, B, & α in terms of $T_{\perp 0}$, $T_{\parallel 0}$, & τ.

What are the values of $T_\perp$ & $T_\parallel$ as $t \to \infty$?

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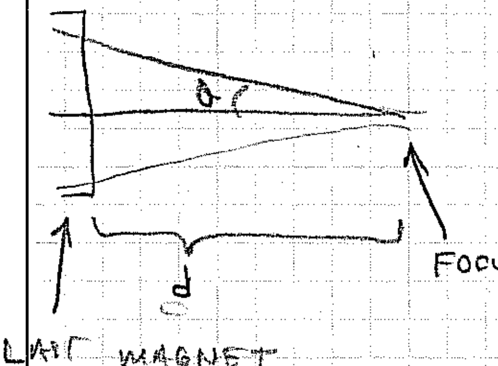
PROBLEM (3) 20 POINTS

1. A mass 200 ion beam has an injection energy $qV = 1$ MeV, a pulse duration $= 10\ \mu s$, a normalized transverse emittance of 1 mm-mrad, and a fractional longitudinal momentum spread $\frac{\Delta p}{p} = 10^{-3}$.

Assume the transverse and longitudinal normalized emittance is conserved, and assume that in the final focus region the beam is neutralized, with a spot size determined by the emittance and chromatic effects only. (Note: the longitudinal normalized emittance $\epsilon_{N\ell} \propto \Delta p\, \ell$, where ℓ is the length of the bunch).

$$r_{spot}^2 \cong \frac{\epsilon^2}{\theta^2} + 3\alpha^2 d^2 \theta^2 \left(\frac{\Delta p}{p}\right)_f^2 \qquad \text{Let } \alpha = 6$$

Here ϵ = the <u>unnormalized</u> emittance, d is the distance between the end of the last magnet and the focal spot, and θ is the half angle of the convergent beam.



a) What is the optimum focusing angle which minimizes the spot radius, (expressed in terms of ϵ, d, & $\Delta p/p_f$)?

What is the radius of the spot if the final ion energy were:
(Assume $d = 6$ m. and final pulse duration $= 10$ ns),

b) 10 GeV?

c) 1 GeV?

d) UNDER THE ASSUMPTIONS OF THIS PROBLEM, SHOW THAT $r_{spot} \sim 1/\beta^n$ where n is a positive real number, and find n.
(Non-relativistic dynamics may be assumed)

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