EXAM for the course of
"Collective Effects in Beam Dynamics" (EM)

SPACE CHARGE

1) What are the 2 effects involved in space charge? Why do we need to compute only the electric field? What happens for very small (high) beam velocity? When in formulae we found $\frac{1}{\gamma^2}$, where does it come from?

2) Rederive the maximum incoherent space charge tune shift of page 15 for the case of a parabolic distribution (given in the "useful relations" in the Introduction) using the smooth approximation.

Compare it to the case of the Gaussian distribution and compute it numerically for the following values:

- Radius of the machine: $R = 1100 \text{ m}$.

- Number of protons in the bunch: $N_b = 1.3 \times 10^{11}$.

- Beam momentum: $p = 26 \text{ GeV/c}$.

- Normalized rms beam emittance: $\varepsilon_{x,rms}^{norm} = \varepsilon_{y,rms}^{norm} = 3 \ \mu\text{m}$.

- Full (4 σ) bunch length: $\tau_b = 4 \text{ ns}$.

3) What is the main difference between a circular beam pipe and an asymmetric beam pipe (for instance 2 parallel plates) as concerns the effect of the images (i.e. the wall)?

WAKE FIELDS AND IMPEDANCES

1) Show that the Panofsky-Wenzel theorem is verified with the equations of page 13.

2) Using the figures of pages 101-104, explain what will be the main effects of these impedances (wake fields) on a beam (considering both a single-bunch and a multi-bunch beam).

COASTING-BEAM TRANSVERSE COHERENT INSTABILITIES

1) Explain what an incoherent tune shift, a coherent tune shift and an incoherent tune spread are. What is the difference between the coherent frequency and the local collective frequency?

2) What is the coasting-beam instability rise-time in the case of the space charge impedance?

3) What is the difference between the spectrum of a coasting beam and the spectrum of a bunched beam?

4) Why do we need to operate a machine with positive chromatic frequency with both a coasting and a bunched beam?

5) What happens in the case of a betatron frequency spread through a nonlinearity only in the horizontal plane if the real part of the horizontal coherent tune shift is –0.7E-3, the imaginary part of the coherent tune shift -1.0E-3 and the tune spread is $\Delta Q_{nl} = \frac{4}{3} 10^{-3}$ (the revolution frequency is 471 kHz)? Is the beam unstable? If yes, what is the instability rise-time and by how much should we increase the tune spread to stabilize the beam? How could we do that?

What happens if the distribution of the incoherent betatron amplitudes is constant?

BUNCHED-BEAM TRANSVERSE COHERENT INSTABILITIES

1) Applying Sacherer's formula (page 51) to the case of a very long bunch (whose length is in fact equal to the ring circumference), show that the same result as for a coasting beam is obtained for the coherent betatron frequency shift in the absence of incoherent betatron frequency spread (for mode m = 0).

2) Looking at Sacherer's formula (51) and the figure of page 56, what happens if the bunch length is doubled or reduced by a factor 2?