Prof. Dr. Albin F. Wrulich EPFL, Winter Term 2005/2006

# Introduction to Particle Accelerator Physics

## Tutorial 4 - Problems

Discussion: 17.1.2006 Hand in: 24.1.2006 Solutions: 31.1.2006

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**1. Quadrupole Errors and Tune Shifts**
In the lecture a quadrupole focussing error was introduced into Hill's equation by replacing the focussing function $K(s)$ with $K(s)+\Delta k(s)$. It was then proposed that the error in the focussing function could be represented as a gradient error $\Delta(kl)$ leading to a tune shift $\Delta Q = \frac{1}{4\pi}\beta_0\Delta(kl)$. Assume that the tune shift is small with respect to the tune and prove this statement.

**2. Momentum Compaction and Transition Energy**
Dispersion leads to path length changes for off-momentum particles. This is characterized by the momentum compaction factor $\alpha_c$ defined in the lecture. Considering that timing is very important in an accelerator, can path length changes be related to a change of the revolution period? Or in mathematical terms, how does $\frac{\Delta T}{T}$ depend on $\frac{\Delta p}{p}$ ? Is it possible to build an accelerator where $\Delta T = 0$ regardless of $\Delta p$ ?

**3. Quadrupole Scan for Emittance Measurement**
Assume a screen monitor downstream of a tunable quadrupole magnet. Show how measuring the beam size $\sigma_x^2$ as a function of quadrupole strength can be used as an emittance measurement.

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Assistant: Simon C. Leemann, simon.leemann@psi.ch, 056/310 3343