

## Problems for Introductory lecture, FFAG School'16, J. Pasternak

1. Show explicitly the conservation of emittance (the Courant-Snyder invariant) .
2. Derive the equation:

$$\frac{\Delta T}{T} = \left( \frac{1}{\gamma_T^2} - \frac{1}{\gamma^2} \right) \frac{\Delta p}{p}$$

3. Prove that the magnetic wedge introduced during the lecture can be represented in thin lens approximation by the matrix:

$$\begin{pmatrix} 1 & 0 & 0 \\ \frac{1}{\rho} \tan \delta & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Explain its focusing properties in horizontal and vertical planes.

4. Open ended question: Consider the magnet for the vertical FFAG introduced in the lectures on scaling FFAG. What would be the fringe field focusing properties in such a magnet?