



# FRIB

## PHY862 Accelerator Systems Introduction to Accelerators

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# Solutions are due by 9/08/2023

**Problem 1.** Find an expression for the fractional error when the nonrelativistic approximation for kinetic energy as a function of  $\beta$  is used. (a) At what values of  $\beta$  and  $\gamma$  does the error in kinetic energy equal 1%? (b) To what kinetic energy does this correspond, for electrons and for protons?

**Problem 2.** The Relativistic Heavy Ion Collider (RHIC) collides fully stripped gold ions ( $A=197, Z=79$ ) at a total energy of  $E_{\text{coll}}=100$  GeV/nucleon per beam. The circumference of each ring is 3834 m. Assume the rest mass of a gold ion is  $197 \times 0.93113$  GeV.

- (a) Calculate the revolution frequency of a particle at the injection energy of  $E_{\text{inj}}=10.5$  GeV/nucleon, and at the storage energy of  $E_{\text{coll}}=100$  GeV/nucleon. What is the change in revolution frequency for particles accelerated from  $E_{\text{inj}}$  to  $E_{\text{coll}}$ ?
- (b) If we assume that there are 192 identical dipoles per ring, each of length  $L=10$  m, what is the required dipole field in each at the collision energy of  $E_{\text{coll}}$ ?

# Problems 3, 4

**Problem 3.** If the only nonzero components of the electromagnetic field in cylindrical coordinates are  $E_r$ ,  $E_z$ , and  $B_\theta$ , write the nonzero components of the Lorentz force for a particle of mass  $m$  and charge  $q$  moving along the  $z$  direction with velocity  $v$ .

**Problem 4.** Please answer the following questions for a proton traveling at a velocity of  $0.9c$ .

- What is its momentum [GeV/c]?
- What is its kinetic energy [GeV]?
- What is its rigidity [T-m]?
- If this proton travels through a 1cm long magnet with a 1T field, by what angle will it be deflected [rad]?