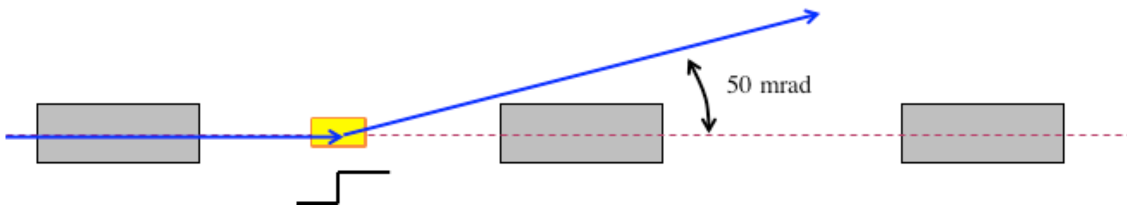
Accelerator Physics Homework 2

1. For a proton beam with kinetic energy of 10 GeV, calculate:
    a. The total energy [GeV]
    b. The momentum [GeV/c]
    c. The velocity [fraction of *c*]
    d. The rigidity $(B\rho)$ [T-m]
2. This beam is circulating in a synchrotron, and we wish to extract it by inserting a small pulsed magnet in a straight section, as shown below.



   In order to clear the next magnet, we need to bend the beam by at least 50 mr.
    a. If we use a 1m long dipole magnet, what field [T] will be required?
    b. In class, we calculated the field of a dipole magnet as
    $$B = \frac{\mu_0 IN}{g}$$
    show that if the length and width of the pole face are *l* and *w*, the inductance is
    $$L = \frac{\mu_0 N^2 wl}{g}$$
    (reminder: inductance is defined as total magnetic flux divided by current)
    c. In order for the beam to fit, our 1 m long extraction magnet has to have *g*=*w*=5cm. To keep inductance low, we use a single turn (that is, *N*=1)
        i. What is the inductance of the magnet [H]?
        ii. What current will be required [A]?
        iii. The beam is circulating, so we need a very fast rise time. If we assume the current rises linearly to the required value in 50 ns, what will be the inductive voltage $\left(V = L\frac{dI}{dt}\right)$ on the magnet [V]? (note: if you did the problem correctly, you'll get an *extremely* large value here).
3. For the beam described above, what magnetic field gradient [T/m] would be required in a 1m long quadrupole to give it a focal length of *f*=50m?
4. If the lattice functions are β=20m and α=0 at the entrance to this quadrupole
    a. What are α, β, and γ at the exit, using the thin lens approximation?
    b. How far away [m] will the minimum β occur, and what will be its value [m]?