Accelerator Physics Homework 1

Here are some general warm-up problems to practice some of the skills which will be required.

1. A matrix operation is defined in the XY plane as  
     
     
     
     
   In a rotated coordinate system where   
     
     
     
     
     
     
     
     
   calculate the elements of the matrix M’, such that   
     
     
     
   (you may assume Det(**M**)=1)



1. *f(x)* and *g(x)* are two solutions to a second order linear homogeneous differential equation. That is,  
     
     
     
   Clearly, any linear combination of these will also be a solution to the equation. In particular we define two new functions  
     
     
   such that   
      
     
     
   Find expression for the constants *a,b,c,* and *d* in terms of the initial values of the original functions and their derivatives



1. Evaluate the following integral  
     
     
   over a volume defined by a cylinder of length L and radius R, oriented along the z axis and centered at the origin.



1. Given the usual definitions of  and , prove the following relationships, which will come in handy:



1. The Fermilab Linac produces a proton beam with kinetic energy of 750 MeV. Calculate the velocity (in m/s), Energy (in MeV) and momentum (in MeV/c) for this beam.
2. The most relativistic (massive) objects created ever created by man were the electrons in the LEP accelerator, which ultimately reached an energy of ~105 GeV per beam.
   1. Calculate (in m/s) the difference between the velocity of these particles and the speed of light.
   2. The circumference of the LEP ring is 27 km. If one assumed that the electrons were going the *exactly* the speed of light, what would be the error in predicted longitudinal position after one full turn.
3. We want to extract a 10 GeV (kinetic energy) beam from a synchrotron. In order to clear the next magnet, we need to bend the beam by at least 50 mr.
   1. If we use a 1m long dipole magnet, what field (in T) will be required?
   2. In class, we calculated the field of a dipole magnet as  
        
        
      show that if the length and width of the pole face are *l* and *w*, the inductance is



* 1. 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)
     1. What is the inductance of the magnet?
     2. What current will be required (in Amps)?
     3. 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 on the magnet? (note: if you did the problem correctly, you’ll get an extremely large value here).