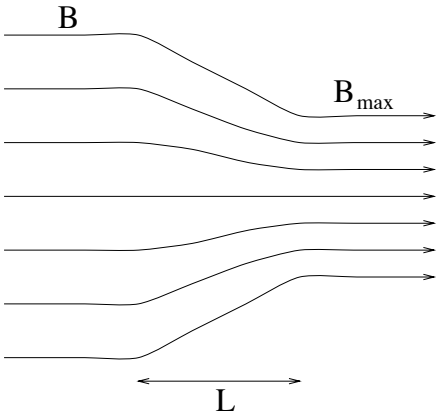
Homework 2

Due **January 30 at 2pm in class**

Please show all work, writing solutions/explanations clearly, or no credit will be given. You are encouraged to work together, but everyone must turn in independent solutions: do not copy from others or from any other sources.

1. A nonrelativistic charged particle moves from a region where the magnetic field strength is B to a region were the field strength has a larger value B_{max}. The distance between these two regions is L, where $L \gg r_c$ and r_c is the cyclotron radius of the orbit of the electron. Write an expression for the minimum value of the initial pitch angle α such that the particle is reflected from the region of B_{max}.



2. In the hot phase of the interstellar gas, the gas is a fully ionized plasma with $T = 3 \times 10^5$ K, $n_e = n_p = 0.003\text{cm}^{-3}$, and $B = 3 \times 10^{-6}$ G. Calculate:

   (a) the Debye length.

   (b) the average Coulomb mean free path of electrons or ions.

   (c) the average electron cyclotron radius.

   (d) the average proton cyclotron radius.

   (e) the average electron cyclotron frequency ω_c.

3. Tycho's supernova exploded in 1572 AD as seen from Earth. The supernova has produced a blast wave in which the surrounding interstellar gas (with an average density of 1 atom/cm^3) was heated to a temperature of 5×10^7 K. Assume the heated gas is fully ionized hydrogen. Estimate whether there has been sufficient time for:

   (a) the electrons to develop a Maxwell–Boltzmann distribution?

   (b) the protons to develop a Maxwell–Boltzmann distribution?

   (c) the electrons and protons to come into equipartition, $T_p = T_e$?

4. A star or planet has a magnetic field which is reasonably well represented as a magnetic dipole field, with a magnetic dipole moment of μ. Assume the field is stationary. Assume the dipole μ can be treated as if it were located at the center of the star or planet. Let r be the radius from the center of the star or planet, and let θ be the co-latitude, the angle measured down from the axis of the dipole.

   (a) Write down an expression for $\vec{B}(r, \theta)$, the magnetic field as a function of r and θ.

   (b) What is the shape of a magnetic field line (give r vs. θ for a line)?