Physics 222 – Test 1 – Spring 2009

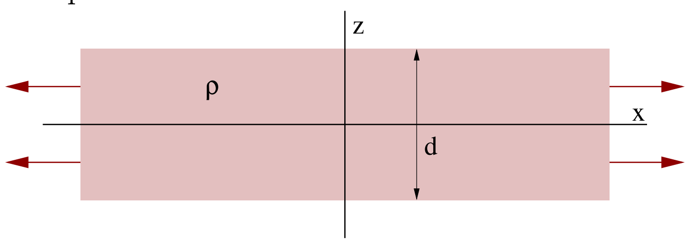
One-page reminder sheet allowed. *Show all work – no credit given if work not shown!*

1. A slab of matter of thickness d and mass density ρ extending infinitely in the x and y directions as shown below creates a gravitational field.

   (a) Describe what symmetries allow you to use Gauss's law to compute the gravitational field in this case.

   (b) Use Gauss's law to compute the gravitational field above and below the slab as a (possible) function of z.

   (c) Compute the field inside the slab as a function of z as well.



2. Suppose the gravitational force law between masses M and $m \ll M$ took the form $F = -AmM/r^4$ where A is a constant and r is the distance between the masses.

   (a) In mass m's orbit around M, are equal areas swept out in equal times? Explain why or why not.

   (b) If mass m moves in a circular orbit around M, derive the relationship between orbit radius and period.

3. Consider a particle of mass m and charge q moving in the x direction under the influence of vector potential $\mathbf{A} = (Cx, 0, 0)$ and scalar potential $\phi = -Cc^2t$ where C is a constant and c is the speed of light.

   (a) Show that the Lorentz condition is satisfied.

   (b) Show that no force acts on the particle from either the scalar or vector potentials.

   (c) Do the kinetic momentum or the kinetic energy of the particle change with time? Explain.

   (d) Given the kinetic momentum $\mathbf{p} = (p, 0, 0)$, determine how the wavelength of the particle changes with x.

4. A free relativistic particle has mass m, charge q, momentum p in the $+x$ direction, and energy $E < 0$. If we were to observe this particle, what would we conclude about

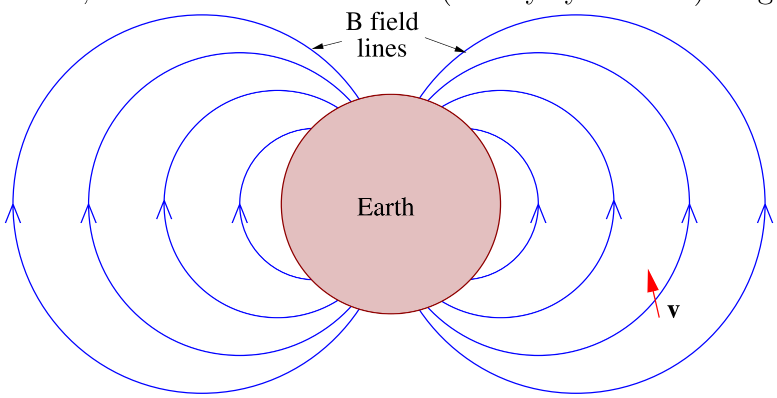
   (a) its mass;

   (b) its charge;

   (c) its direction of motion;

   (d) its energy?

5. Knowing what you do about the motion of charged particles in magnetic fields, describe qualitatively how a positively charged particle starting with velocity $\mathbf{v}$, as illustrated below, will move in the Earth's (axially symmetric) magnetic field.



6. An electric drill makes a circular loop of wire of radius R rotate with angular frequency ω as shown below.

   (a) If a magnetic field of magnitude B is oriented normal to the axis of rotation, determine the EMF around the loop as a function of time.

   (b) If the EMF is measured by a recording voltmeter as shown, describe how the voltmeter reading (as a function of time) could be used to determine the magnetic field.