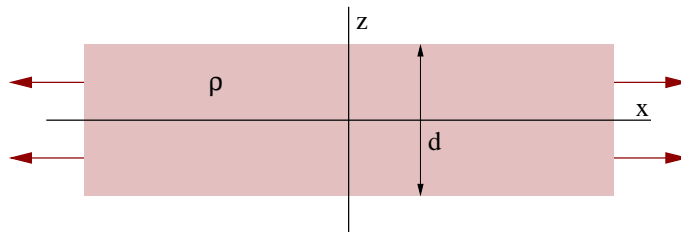


# Physics 222 – Test 1 – Spring 2009

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  $\rho$  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.

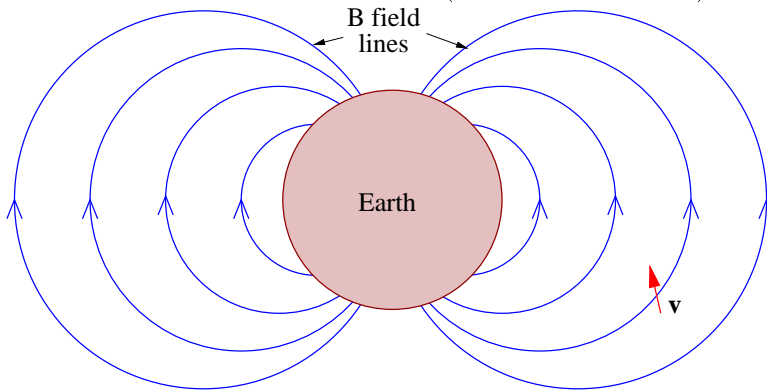


2. Suppose the gravitational force law between masses  $M$  and  $m \ll M$  took the form  $F = -AmM/r^4$  where  $A$  is a constant and  $r$  is the distance between the masses.
  - (a) In mass  $m$ 's orbit around  $M$ , are equal areas swept out in equal times? Explain why or why not.
  - (b) If mass  $m$  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  $\phi = -Ct^2$  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  $\omega$  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.

