Physics 222 – Test 1 – Spring 2010

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

1. Consider an infinite circular cylinder of matter with radius R and constant mass density ρ.

   (a) List the constraints imposed by the symmetry of the cylinder on the direction of the gravitational field vector and on its variation in magnitude (or lack thereof) along and around the cylinder. Draw a picture illustrating your conclusions.

   (b) Use Gauss's law to determine the magnitude of the gravitational field outside the cylinder as a function of r, the distance from the cylinder axis.

   (c) Use Gauss's law to determine the field as a function of r inside the cylinder.

2. Derive the equivalent of Kepler's third law ($T^2 \propto r^3$) for the special case of a circular orbit, but with an alternative gravitational force law

$$F = -\frac{mMC}{r}$$

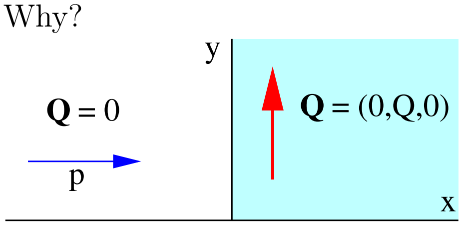
   where m is the mass of the planet, M is the sun's mass, and C is a constant.

3. A particle moving in the $+x$ direction with kinetic momentum p in a region with zero potential momentum crosses into a region defined by $x > 0$ in which the potential momentum points in the y direction with constant magnitude Q. The potential energy of the particle is zero everywhere, so the kinetic energy of the particle is conserved.

   (a) Compute the y component of the kinetic momentum of the particle for $x > 0$.

   (b) Compute the x component of the kinetic momentum for $x > 0$, given the above result.

   (c) For what values of Q does the particle fail to penetrate into the region $x > 0$? Why?



4. A virtual particle decays into two real particles, a stationary electron of mass m, and a massless photon of energy E moving in the $+x$ direction.

   (a) Compute the energy E_V of the virtual particle.

   (b) Compute the momentum p_V of the virtual particle.

   (c) From the above two results, compute the mass m_V of the virtual particle.

5. Given an electromagnetic four-potential

$$\underline{\mathrm{a}} = (Cyt, Dy, 0, \phi/c)$$

   where the scalar potential ϕ is to be determined and C and D are constants:

   (a) Find a form of the scalar potential ϕ such that the Lorentz condition is satisfied.

   (b) Compute the electric field, given the above ϕ.

   (c) Compute the magnetic field.

6. Describe qualitatively the motion of a charged particle in the magnetic field illustrated below, wherein the field lines converge at the left and right ends, yielding stronger fields there. Hint: Be very careful in determining which way the Lorentz force points at each end as the particle spirals along the field lines.