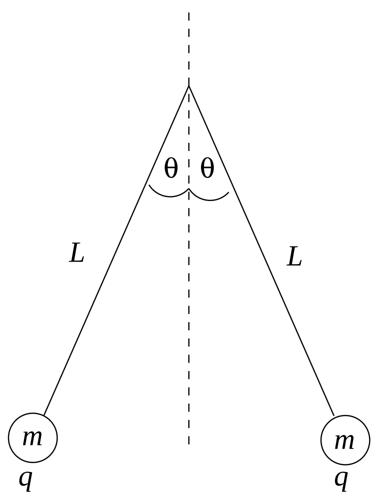
Note: hand in questions 1 and 2 as homework; we will work 3 and 4 in class on Tuesday.

1. Two small spheres of mass m are suspended from a common point by threads of length L. When each sphere carries a charge q, each thread makes an angle θ with the vertical as shown in the figure. Find an expression for the charge q at equilibrium in terms of L, m, g, θ, and the Coulomb constant k.



2. After improvements in magnet technology reduce the cost, physicists propose building a circular accelerator around the Earth's circumference using bending magnets that provide a magnetic field of 2 T.

Remember that $c = 3 \times 10^8$ m/s, 1 eV $= 1.6 \times 10^{-19}$ J, the rest mass of the proton is 938 MeV/c^2, the radius of the Earth is 6.4×10^6 m, and the charge of a proton is 1.6×10^{-19} m.

a) Find the momentum of a proton going around this accelerator.

b) What is the kinetic energy of the protons orbiting in this accelerator? State any assumptions that you make.

c) Find the period of rotation of the protons.

3. A sphere of radius a carries a charge density proportional to the distance from the center of the sphere, $\rho(r) = kr$.

a) Derive expressions for the electric field, both inside and outside of the sphere.

b) Derive expressions for the electric potential, again both inside and outside of the sphere. Use infinity as your reference point (i.e. the electric potential at $r = \infty$ is zero).

c) If the sphere's radius is $a = 2.0$ cm, and the total charge carried by the sphere is 50 μC, find the magnitude of the electric potential at the surface of the sphere [note: $\epsilon_0 = 8.85 \times 10^{-12}$ $C^2/(Nm^2)$].

4) A loop of wire of resistance R, containing a coil of self-inductance L encloses an area A. A spatially uniform magnetic field is applied perpendicular to the plane of the loop with the following time dependence: for $t < 0$ the field is zero; for $0 < t < t_0$, $B(t) = kt$, while for $t > t_0$ the field now remains constant at $B_0 = kt_0$. Calculate the current I in the loop for all time $t > 0$, given that $I = 0$ for $t = 0$.