Homework3

Problem 1

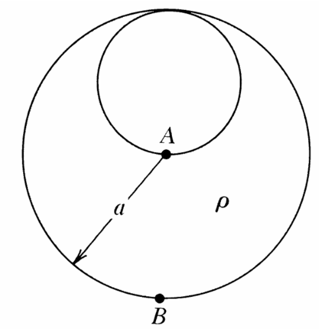
In the domain of elementary particles, a natural unit of mass is the mass of a nucleon, that is, a proton or a neutron, the basic massive building blocks of ordinary matter. Given the nucleon mass as $1.67 \cdot 10^{-27}\mathrm{kg}$ and the gravitational constant G as $6.67 \cdot 10^{-11}\mathrm{m}^3/(\mathrm{kg\,s}^2)$, The distance between the two protons in the helium nucleus could be at one instant as much as $10^{-15}\mathrm{m}$. Compare the gravitational attraction of two protons with their electrostatic repulsion. This shows why we call gravitation a very weak force. Then how large is the force of electrical repulsion between two protons at that distance?

Problem 2

A spherical volume of radius a is filled with charge of uniform density ρ. We want to know the potential energy U of this sphere of charge, that is, the work done in assembling it. Calculate it by building the sphere up layer by layer, making use of the fact that the feld outside a spherical distribution of charge is the same as if all the charge were at the center. Express the result in terms of the total charge Q in the sphere.

Problem 3

The sphere of radius a was filled with positive charge at uniform density ρ. Then a smaller sphere of radius $a/2$ was carved out, as shown in the figure, and left empty. What are the direction and magnitude of the electric field at A? At B?

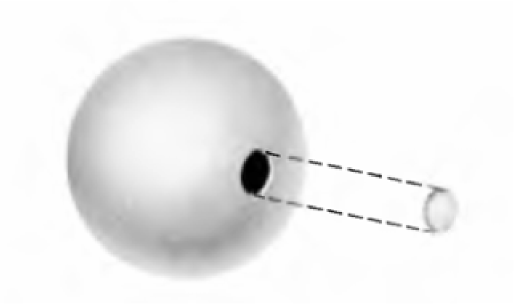


Problem 4

Consider a distribution of charge in the form of a circular cylinder, like a long charged pipe. Prove that the feld inside the pipe is zero. Prove that the feld outside is the same as if the charge were all on the axis. Is either statement true for a pipe of square cross section on which the charge is distributed with uniform surface density?

Problem 5

The figure shows a spherical shell of charge, of radius a and surface density σ, from which a small circular piece of radius $b \ll a$ has been removed. What is the direction and magnitude of the field at the midpoint of the aperture? There are two ways to get the answer. You can integrate over the remaining charge distribution to sum the contributions of all elements to the feld at the point in question. Or, remembering the superposition principle, you can think about the effect of replacing the piece removed, which itself is practically a little disk. Note the connection of this result with our discussion of the force on a surface charge—perhaps that is a third way in which you might arrive at the answer.



Problem 6

A charged soap bubble experiences an outward elcctrical force on every bit of its surface. Given the total charge Q on a bubble of radius R, what is the magnitude of the resultant force tending to pull any hemispherical half of the bubble away from the other half? (Should this force divided by $2\pi R$ exceed the surface tension of the soap film interesting behavior might be expected!)