General Physics: Electromagnetism, Problem Set 4

Exercise 1 :

We assume an electron beam is a stationary uniform charge distribution in cylindric form with radius a and infinite length.

(a) Find the electric field at a distance r from the beam center for $r > a$ and $r < a$. Assume a line charge density of λ of the electron beam.

(b) What is the force on an electron in the beam at a distance r from the beam axis if you assume a volume charge density of n electrons per unit volume V?

Exercise 2 :

A long, straight wire is surrounded by a hollow metal cylinder whose axis coincides with that of the wire. The wire has a charge per unit length of λ, and the cylinder has a net charge per unit length of 2λ. From this information, use Gauss's law to find:

(a) The charge per unit length on the inner surface of the cylinder;

(b) The charge per unit length on the outer surface of the cylinder;

(c) The electric field outside the cylinder a distance r from the axis.

Exercise 3 :

Calculate the Electric Field within and outside a charged cylinder of radius R and length L with a charge density obeying the law $\rho(r) = \rho_0(a - br)$, where a and b are arbitrary parameters. Consider the case where $L \gg R$, which means that the direction of the electric field lines are radial.

- **Hint 1**: remember that the electric field is radial, so try to take a proper Gaussian surface to easily compute the electric field flux (left part of Gauss's law);
- **Hint 2**: to compute the integral of the charge density, move to cylindrical coordinates.

Exercise 4 :

Consider a spherical cavity of radius a at the center of a non-conductive sphere of radius R. The volume charge density in the rest of the sphere varies according to $\rho = A/r$, where A is a positive constant. Determine the electric field for $a < r < R$.

- **Hint**: the charge inside a shell of thickness dr is $dq = \rho dV = \rho(4\pi r^2)dr$.

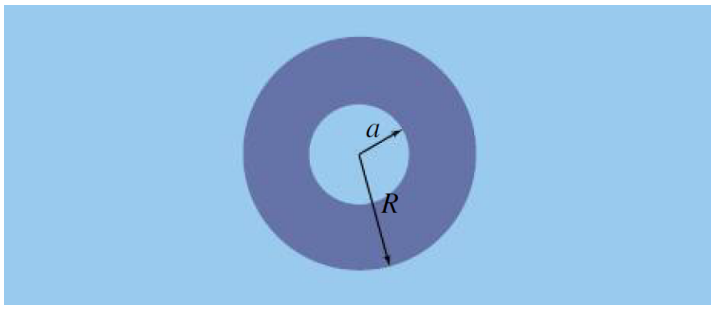

Figure 1: Spherical cavity of radius a at the center of a non-conductive sphere of radius R.

Exercise 5 :

Two non-conducting spheres of radii R_1 and R_2 are uniformly charged with charge densities ρ_1 and ρ_2, respectively. They are separated at center-to-center distance a (see below). Find the electric field at point P located at a distance r from the center of sphere 1 and is in the direction θ from the line joining the two spheres assuming their charge densities are not affected by the presence of the other sphere.

- **Hint**: Work one sphere at a time and use the superposition principle.

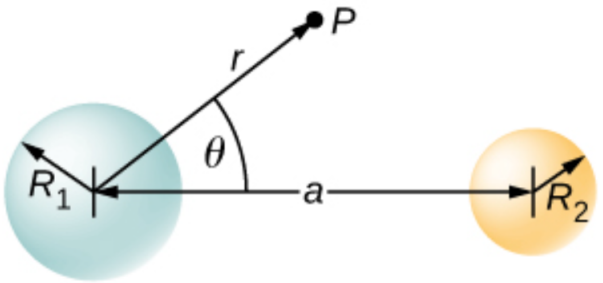

Figure 2: Two non-conducting spheres of radii R_1 and R_2, uniformly charged with charge densities ρ_1 and ρ_2, respectively.

Exercise 6 :

A very large (infinite), uniformly charged slab of plastic of thickness $2a$ occupies the region between the $z = -a$ plane and the $z = +a$ plane. Find the electric field everywhere due to this charge configuration. The charge per unit volume of the plastic is ρ.