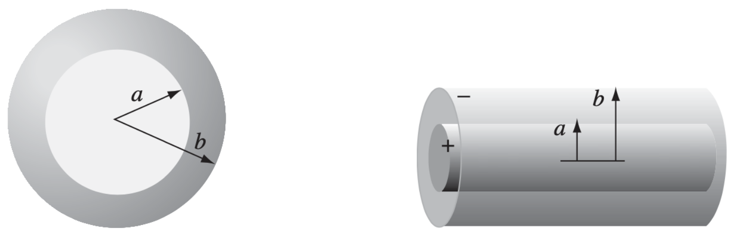
Advanced Electrodynamics, Homework Set 1

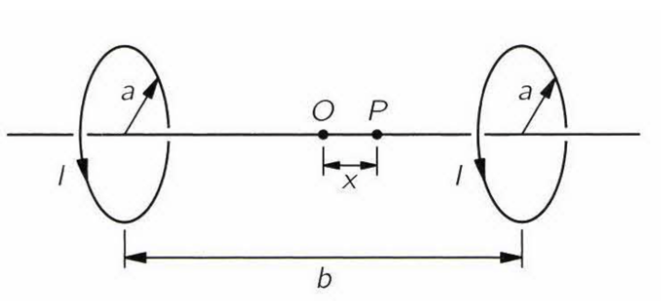
Deadline: Thursday February 15, 12:00 (noon)

0. Review Griffiths, Introduction to Electrodynamics, Chapters 1, 2, 5, 7.

1. A long coaxial cable (see the Figure) carries a uniform volume charge density ρ on the inner cylinder (radius a), and a uniform negative surface charge density on the outer cylindrical shell (radius b), such that the cable as a whole is electrically neutral. Find the electric field in the three regions: (i) inside the inner cylinder ($s < a$), (ii) between the cylinders ($a < s < b$), (iii) outside the cable ($s > b$). Plot $|\vec{E}|$ as a function of s.



2. In practical magnetic structures, uniform fields are often necessary. Consider so-called Helmholtz coils, or two coaxial loops that carry currents in the same direction. Assume the coils have radius a, axes on the x-axis, carry a current I each, and are separated by a distance b (see the Figure).



   a. Find the magnetic field at point P on the axis of the loops at distance x from mid-point O.
   b. Expand the expression for the field in a power series, and keep terms to order x^2.
   c. Which relation must hold for a and b such that the x^2-terms vanish? What is the significance of this?
   d. Show that the field created by the coils to the order and under the condition found in part (c) is given by $B_x = 8\mu_0 I/(5^{3/2}a)$.

3. a. Find the density of mobile charges in a piece of copper. (Each atom contributes one free electron.) Look up the required physical constants.
   b. Calculate the average electron velocity in a copper wire 1 mm in diameter, carrying a current of 1 A.
   c. What is the attractive force between two such wires, 1 cm apart?
   d. Suppose you could remove the stationary positive charges, what would the repulsive electrical force be? Compare it to the magnetic force.