Physics 108: Principles and Applications of Electricity and Magnetism
Wellesley College, Fall 2024

Problem Set 9

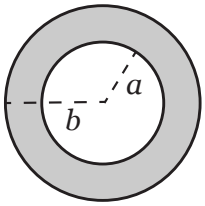
Distributed: Sunday November 10, 2024
Due: 10 PM on Monday November 18, 2024

Problems

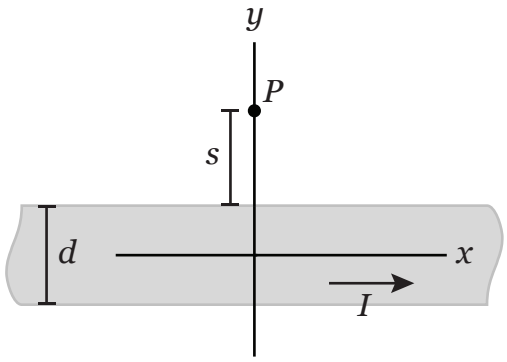
1. In the "semi-classical" model of the hydrogen atom (also known as the "Bohr model"), the electron orbits the nucleus in certain circular orbits called "stationary states". In the ground state of the atom, the electron is assumed to travel in a circular orbit of radius of $a_0 = 5.3 \times 10^{-11}\,\text{m}$, where a_0 is called the "Bohr radius".
   (a) Apply $\vec{F} = m\vec{a}$ to the electron to express the electron's speed v in terms of a_0 and other constants (m_e, k, e).
   (b) Using your result from (a), express the frequency of the electron's orbit in terms of a_0 and other constants.
   (c) The magnitude of the current associated with the circulating electron is equal to the electron's charge multiplied by the frequency of the orbit. Express I in terms of a_0 and other constants.
   (d) Find an expression for the magnetic dipole moment of the circulating electron and calculate its numerical value using your prior knowledge of the values of k, m_e, and e.

2. A single turn circular loop of radius $R = 12\,\text{cm}$ carries a current of $I_1 = 13\,\text{A}$. A second circular loop sits at the center of the large loop, with its plane oriented 90 degrees relative to the large loop. This smaller loop has a radius of $a = 0.82\,\text{cm}$ with 50 turns, carrying a current of $I_2 = 1.3\,\text{A}$.
   (a) What is the magnitude of the magnetic field from the large loop at its center?
   (b) Find the magnitude of the torque that acts on the small loop. You can assume the magnetic field due to the large loop is essentially uniform throughout the volume occupied by the small loop.

3. An infinitely long cylindrical pipe carries a uniformly distributed total current I into the page. The pipe has an inner radius of a and an outer radius of b as shown below. Find an expression for the magnetic field (including direction) in three regions:
   (a) Outside the pipe, $r > b$.
   (b) In the solid area of the pipe, $a < r < b$,
   (c) In the hollow region of the pipe, $r < a$.



4. A thin strip of metal lies in the x-y plane with infinite length in x and width d in y. A current I flows along the conductor in the $+x$ direction, as shown in the diagram below. Find the magnetic field at a point P a distance s from the edge of the strip along the y axis. (Hint: consider treating the strip as the sum of many infinitely thin wires carrying a fraction of the current dI.)



5. A square loop of wire sits in the $x-y$ plane with one corner at the origin, as shown below. The loop has sides of length L. A non-uniform, time-varying magnetic field is directed out of the page in the $\hat{z}$ direction. The field magnitude given by $B(x, y, t) = B_0 y t^2$, where B_0 is a constant with the appropriate units. Determine:
   (a) The magnetic flux through the loop $\Phi_B(t)$.
   (b) The direction of the induced current in the loop.
   (c) An expression for the induced emf in the loop $\mathcal{E}(t)$.