Homework 0

Warm-ups

Ex 1.1: Thomson's Jumping Ring

In class you saw a demonstration of 'Thomson's jumping ring': A conducting ring placed around the upper half of a solenoid was propelled upwards once the solenoid was connected to AC power (see figure with coordinates labelled).

a) Draw the magnetic fields lines produced by the solenoid when the current in the solenoid is non-zero.

b) Let the magnetic field be $\boldsymbol{B}(r, z, t) = \boldsymbol{B}(r, z) \sin(\omega t)$ and assume the ring has radius a and zero resistance. Use Faraday's law and the Lorentz force law to derive an expression for the force acting on the ring at any time t (you need not find $\boldsymbol{B}(r, z)$ explicitly). Deduce that there is always an upwards force on the ring.

c) *Extra Challenge: What happens if the ring has a non-zero resistance?*

Hint: Divide the magnetic field into radial and axial components. Keep in mind that the ring has an inductance!

Ex 1.2: Coaxial cable

A long coaxial cable carries a uniform volume charge density ρ on its solid inner cylinder (radius a) and a uniform surface charge density on its outer cylindrical cylindrical shell (radius b). This surface charge is of just the right value so that the cable as a whole is electrically neutral.

a) Find the electric field in each of the three regions:

    i) inside the inner cylinder $r < a$;

    i) between the cylinders $a < r < b$;

    i) outside the cable $r > b$.

b) Sketch a graph the electric field strength and the electric potential as a function of r, assuming that the potential is zero at $r = 0$.

Ex 1.3: Lorentz Force and Newton's Third Law

Consider two infinitesmal current line elements $I_1 d\boldsymbol{l}_1$ and $I_2 d\boldsymbol{l}_2$. By sketching these current elements and the Lorentz forces they produce on each other, so that there exists an orientation of these current elements such that Newton's third law does not hold. Be sure to include on your sketch the infinitesmal magnetic field each element produces at the location of the other element. *Extra challenge: Is the 3rd law really violated here, or did we miss something?*