Physics 110B - Midterm 1

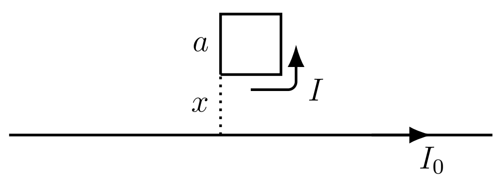
Friday, February 11, 10-11AM, in PAB 1434A

UCLA / Winter 2022 / Brian Naranjo

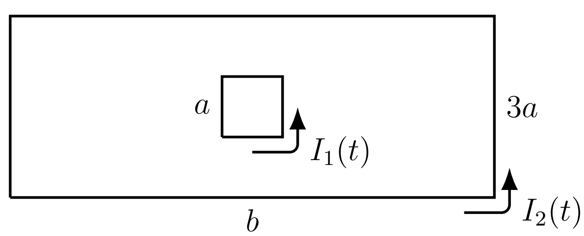
- You may use a single letter-sized paper with handwritten notes, front and back.
- I will provide any requested integral.
- No electronic devices.
- If you finish early, you may hand in your test and leave.
- This test will be curved so that at least 30% of you will receive an A. It is written to give a broad distribution of scores, so please don't despair if it is difficult.

Problems

1) (10 points) An infinite wire carries current I_0. A square loop of side length a and resistance R is positioned in the plane of the wire, a distance x from the loop, as shown. You pull the loop away from the wire with velocity $v = dx/dt$ such that a steady current I is maintained in the loop. As a function of x, what is the velocity v?



2) (10 points) A square loop of side length a is located in the center of a rectangular loop of length b, width $3\,a$ and resistance R_2, as shown below. If a time-varying current $I_1(t)$ flows in the square loop, what is the induced current $I_2(t)$ in the rectangular loop? Assume that positive values of I_1 and I_2 flow in the counterclockwise direction, as shown. You may assume that $a \ll b$ and that there are no multiple inductive reactions.



3) (10 points) There are two infinitely long coaxial cylindrical thin shells whose axes coincide with the z axis. The inner shell has radius a and carries a uniform linear charge density λ, while the outer shell has radius b and carries a uniform charge density $-\lambda$. Both are traveling with velocity $\mathbf{v} = v\hat{\mathbf{z}}$. Find the Poynting vector $\mathbf{S}$ everywhere and then find the net flow of electromagnetic energy through the xy plane,

$$\int_{z=0} (\mathbf{S} \cdot \hat{\mathbf{z}})\, dx\, dy$$

4) (10 points) Point charge $q_1 = q$ is at $\mathbf{r}_1 = a\hat{\mathbf{z}}$, and point charge $q_2 = q$ is at $\mathbf{r}_2 = -a\hat{\mathbf{z}}$. Use the Maxwell stress tensor $\overleftrightarrow{\mathbf{T}}$ to find the net force on point charge q_1.