University of Louisville
College of Arts and Sciences

Department of Physics and Astronomy PhD Qualifying Examination (Part I)

Fall 2014

Paper B – Electromagnetism

Time allowed – 90 minutes

Instructions and Information:

- Answer both questions
- This is a closed book examination
- Start each question on a new sheet of paper – use only one side of each sheet
- Write your identification number on the upper right hand corner of each answer sheet
- You may use a non programmable calculator
- Partial credit will be awarded.
- Correct answers without adequate explanations will not receive full credit.
- Make sure your work is legible and clear
- The points assigned to each part of each question is clearly indicated

E&M Basic

Two long, parallel, cylindrical wires, each of radius a, whose centers are a distance d (d> 2a) apart carry equal currents, I, in opposite directions.

(a) Obtain an expression for the **B** field in the plane formed by the axes of each cylinder a distance y from one of the axes. (11)

(b) Sketch the configuration described above, indicating the direction of the current in each wire and the direction of the **B** field at a point a distance y from one of the wires. (3)

(c) Assuming that the wires are part of a circuit completed "at infinity", obtain an expression for the magnetic flux between a length ℓ of the wires. (16)

(d) Determine the self inductance of a length ℓ of this circuit. (5)

E&M Intermediate

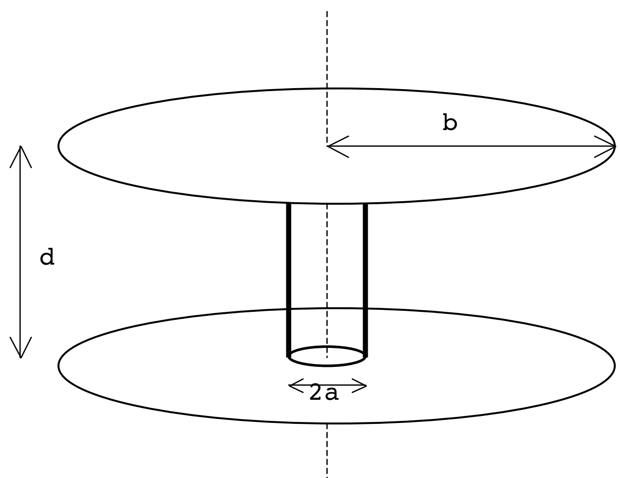
A region of space with volume V within a closed surface s contains electromagnetic fields (**E**, **B**) of energy density u and free current density $\mathbf{J_f}$. Poynting's theorem, resulting from the application of the principle of conservation of energy to the volume V, can be written as follows,

$$\int_V \left(\frac{\partial u}{\partial t} + \nabla \cdot \mathbf{S} + \mathbf{J}_f \cdot \mathbf{E} \right) d\tau = 0$$

where **S** is the Poynting vector.

(a) Explain the physical significance of each term in the above equation. (9)

A capacitor comprising two circular parallel plates of radius b and plate separation d << b is charged to a voltage V. A cylindrical conductor, length d, radius a and resistance R (a << d << b) is then connected between the two plates at their center to discharge the capacitor.



(b) Derive an expression for the **B** field between the plates as a function of radius, $\rho > a$ and the current, I, flowing through the resistor at any given time. (21)

(c) Explain qualitatively why the **B** field at the edge of the capacitor goes to zero. (8)

(d) Use the Poynting vector to show that the instantaneous flow of energy into the resistor through its surface is I^2R where I is the current flowing through the resistor. (17)

(e) The experiment is repeated with the resistor replaced by an ideal solenoid (having no resistance) also of radius a. Estimate the maximum **B** field which appears inside the solenoid when the separation between the plates d = 10 μm, the voltage V = 1000 V and b/a = 100. (10)