PHY 218 **Midterm Exam** **Spring 2015**

1) [40 points total]

a) [10 pts] Explain why it was necessary to use electro*dynamics* in order to calculate the energy stored up in a set of loops carrying steady, time independent, currents. Why could we not have calculated this from our knowledge of electro- and magnetostatics? You do not need any detailed calculation, just explain in words the main point.

b) [10 pts] Explain what is meant by a a gauge transformation in the context of electro*dynamics*. Don't just give some equations, but explain in words the main points.

c) [10 pts] Ampere's law in magneto*statics* is: $\nabla \times \mathbf{B} = \mu_0 \mathbf{j}$. Explain why this equation can no longer hold true once one considers time varying situations. Don't just give the new correct equation, explain why the magnetostatic equation can't continue to be correct.

d) [10 pts] Show that one can describe an electromagnetic plane wave in a vacuum by scalar and vector potentials such that $V = 0$ and $\mathbf{A} \neq 0$. Find the appropriate $\mathbf{A}$ and explicitly show that it gives electric and magnetic fields with the correct properties of a wave in the vacuum.

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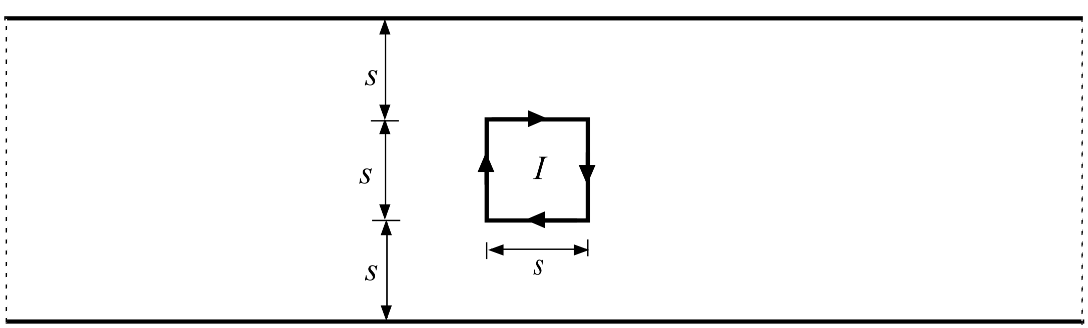
2) [30 points total]

A square loop of wire with side length s lies midway between, and in the same plane as, two long straight parallel wires separated a distance $3s$ – you may consider the long straight wires as the sides of a very large rectangular loop, but the short ends are so far away that they can be neglected. See the diagram below.

A clockwise current I in the square loop is gradually increasing with $dI/dt = k$, ($k > 0$ is a constant). Find the emf induced in the large rectangular loop. Which way will the current induced in the large rectangular loop flow? [*Hint*: compute the mutual inductance of the two loops, and use that to find the answer.]



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problem 3 on back side!

3) [30 points total]

Consider a very long straight cylindrical wire of length L and radius a, carrying a uniform steady current I distributed evenly over the cross-sectional area of the wire. If the wire has a uniform resistance per unit length, R/L, then there will be a voltage drop down the length of the wire, $V = IR$, and an electric field in the wire, $E = V/L$.

Compute the Poynting vector exactly on the surface of the wire. Find the rate of electromagnetic energy flowing through the surface of the wire (assume that L is so long that you may ignore effects at the ends of the wire). Does the energy flow into or out of the wire? Your answer should look familiar. Give a physical explanation for your result.