Name: ______________________________.

Emory University
Department of Physics
Physics 511A Dr. I. Nemenman Spring 2014
March 3, 2014

Exam I

INSTRUCTIONS

1. Write your full name on every page. This is important in case the pages become separated during grading.
2. The solutions are due by **10 am, Friday, March 7** in my mailbox.
3. Limit your time on solving the exam to not more than **4 hours**.
4. Solve **6 problems out of 8**; choose any 6 you want.
5. Your answers will be evaluated in part on how you got them. LITTLE OR NO CREDIT MAY BE EARNED FOR ANSWERS THAT DO NOT SHOW HOW YOU GOT THEM. Partial credit will be given for correct steps shown, even if the final answer is wrong.
6. Write clearly and logically so I can understand what you are doing and give you as much partial credit as you deserve. I obviously can't give you credit for what you are thinking... only for what you show on your paper.
7. This exam is open book and notes. No person-to-person and electronic communications allowed. That is, you must work alone, and without consulting the internet.
8. Maximum score for each problem is 10.
9. **The Emory Honor Code applies to your work on this examination.**

1	2	3	4	5	6	Total
of 10	of 10	of 10	of 10	of 10	of 10	of 60

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1. Calculate the dipole and the quadrupole moments of four equal negative charges in the vertices of a square, and a positive charge of four times the size of each negative charge positioned at the center of the square. Use the center charge as the origin. How do the moments change if the origin is moved to coincide with one of the vertices? Draw the electric field pattern for this charge configuration. Be sure to choose the scale of your drawing to show all of the salient features of the pattern.

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2. A cylindrical column of electrons has uniform volume charge density ρ and radius a.
(a) Find the force on an electron at a radius $r<a$.
(b) A moving observer sees the column as a beam of electrons, each moving with a speed of v. What force does this observer report is felt by the same electron?

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3. In a certain reference frame, $H=0$, and $E\neq 0$. Is it possible, using a Lorentz boost, to make $E=0$, and $H\neq 0$? Explain. If this is possible, find the magnitude and the direction of the velocity vector that would achieve this.

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4. The action for a relativistic point particle coupled by a strength g to a space-time-dependent Lorentz scalar field $\varphi(x)$ is

$$S = -mc\int ds - g\int ds\,\varphi.$$

Find the equation of motion for the particle. How does the force on the particle differ from the Coulomb force in the electric field?

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5. A small loop of radius r with positive charge Q evenly distributed through it is rotated about its symmetry axis to form a current j. What is the Poynting vector far away from this loop?

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6. Suppose the photon had a mass. Then the Poisson equation would change to

$$\Delta\phi = -4\pi\rho + \frac{\phi}{L^2},$$

where the length scale would be defined as $L = \hbar/mc$. A point charge q is put in the center of origin. What is the electric potential produced by this charge? What would be the Coulomb force for interaction of two such charges?

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7. A point dipole charge density can be represented as $\rho(\vec{r}) = q_i \nabla_i \delta(\vec{r} - \vec{r}_0)$.

(a) How would you represent the charge density corresponding to a point quadrupole?

(b) The point quadrupole is in an electric field $\vec{E}(\vec{r})$. What is the force acting on it?

(c) The point quadrupole is in a field of a point charge Q. What it the force acting on it? What is the torque acting on it?

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8. Simplify the expressions

$\vec{\nabla}\times(\vec{a}\times\vec{r}) =$

$\epsilon_{ljk}\epsilon_{ijk} =$

$(\vec{a}\cdot\hat{n})\hat{n} + (\vec{a}\times\hat{n})\times\hat{n} =$