**Physics 305 – Sample Final Exam**

There are four problems on this exam. Each problem is worth 25 points. Start each problem on a new sheet of paper, and use only one side of each sheet. GOOD LUCK !!!

(1) A particle with charge $q$ is moving with constant speed $\beta c$ along the $z$ axis. Use the tools that we developed in Chapter 12 to determine the electric and magnetic fields at an arbitrary point in space at the time $t=0$ when the particle passes through the origin. Express your answers in cylindrical coordinates.

(2) Consider two thin, concentric spherical shells with radii $a$ and $b$ (with $a < b$). The region in between the two shells is filled with a material that has relative dielectric $\varepsilon_r = 1$, relative permeability $\mu_r = 1$, and conductivity $\sigma$. At $t=0$, there is a total charge $+Q_0$ on the inner shell and $-Q_0$ on the outer shell. Assume the conductivity is small enough so that retardation effects can be neglected.

(a) Find the electric and magnetic fields throughout space for all times $t>0$. Be sure to justify any assumptions that you make.

(b) Show that your fields from part (a) obey Maxwell's equations.

(3) The Bohr planetary model of the atom was a natural outgrowth from Rutherford's discovery of the atomic nucleus. But there was a problem! Bohr's model had an electron with charge $-e$ moving with constant speed $v$ in a circle of radius $a$ in the $x$-$y$ plane, centered on the origin. Classically, such a system should radiate and lose energy. Calculate the intensity distribution of the emitted radiation, $dP/d\Omega$, and the average total power radiated. Note that, in the Bohr model, $v << c$, so the long-wavelength approximation is valid.
**Side comment**: The calculated total power isn't too far off for excited states in the hydrogen atom, but it fails miserably for the *ground* state.

(4) My former post-doc, now an Assistant Professor at James Madison University, would like to perform an experiment that requires a tunable, mono-energetic beam of 5-10 MeV gamma rays. Such a beam can be produced by shining light from a tunable dye laser operating in the IR or visible range (photon energies of <1 to a few eV) into a high energy electron beam (typical electron energies for this purpose are in the range of 0.5 to 5 GeV), as shown in the figure below. If Adriana places her target where it will see only those laser photons that backscatter off the electron beam in a narrow cone at $180^0$, it will see mono-energetic gamma rays. Calculate the energy of the gamma rays, $E_{\gamma,f}$, expressed in terms of the incident photon energy $E_{\gamma,i}$, the electron beam energy $E_{e,i}$, the mass $m$ of the electron (note: $mc^2 \approx 0.5$ MeV), and any physical constants that you need.
**Note**: Adriana needs to know the gamma ray energy to within ~0.1% (*i.e.*, around 10 keV). So it will be okay to make approximations that change the answer less than that. If you find you must make an approximation that has a larger impact on your final answer, also estimate the error in your answer arising from your approximation.