PHY 415 **Midterm Exam** **Fall 2013**

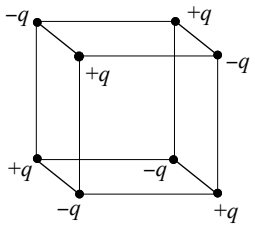
1) [50 points total]

In each of the following situations, the electric field **E** or magnetic field **B** will decay with the distance r from the source as some power of the distance, i.e. as $1/r^n$. For each situation, give the value of n. You do not need to give a full calculation, but you must convincingly state the reason for the value of n in each case.

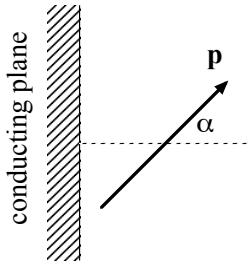
a) A thin spherical shell of radius R, is centered on the origin, with a surface charge density of $\sigma(\theta) = \sigma_0 \cos^3(\theta)$. Here σ_0 is a constant, and θ is the usual spherical angular. [10 pts]

b) A disk of radius R in the xy plane at $z = 0$, is centered on the origin, with surface charge density $\sigma(r) = C \sin(2\pi r/R)$. Here r is the radial distance from the center of the disk. [10 pts]

c) Eight point charges are located at the corners of a cube with side of length a, as shown below. The charges are all of equal magnitude, but alternate in sign as one goes around any of the faces of the cube. [10 pts]



d) An electric dipole **p** is oriented at an angle of α with respect to an infinite flat grounded conducting plane, as shown below. We are interested in the electric field far from the dipole, in front of the conducting plane. What is the value of n when $\alpha = 0°$, $45°$, $90°$? [10 pts]



e) Two circular wire loops, each of radius R, are centered about the origin in the xy plane, one at height $z = +d/2$, the other at height $z = -d/2$. The first has current I circulating counterclockwise, the second has current I circulating clockwise. Assume d and R are of comparable length. [10 pts]

2) [50 points total]

A thin spherical shell of radius R carries a uniform surface charge density $+\sigma_0$ on the northern hemisphere, $0 < \theta < \pi/2$, and an equal but opposite uniform surface charge density $-\sigma_0$ on the southern hemisphere, $\pi/2 < \theta < \pi$. Calculating the coefficients in the Legendre expansion up to $\ell = 6$,

a) find the electrostatic potential outside the sphere. [25 pts]

b) find the electrostatic potential inside the sphere. [25 pts]

Legendre Polynomials:

$$P_0(x) = 1 \qquad P_4(x) = \tfrac{1}{8}(35x^4 - 30x^2 + 3)$$

$$P_1(x) = x \qquad P_5(x) = \tfrac{1}{8}(63x^5 - 70x^3 + 15x)$$

$$P_2(x) = \tfrac{1}{2}(3x^2 - 1) \qquad P_6(x) = \tfrac{1}{16}(231x^6 - 315x^4 + 105x^2 - 5)$$

$$P_3(x) = \tfrac{1}{2}(5x^3 - 3x)$$