

**Physics 380-001**  
**Homework #5**

**1. Poles (4 pts):** Do problem 3.27 in textbook.

**2. More poles (6 pts):** Do problem 3.30 in textbook. In addition, find the electric field.

**3. Fundamental Concept [6 pts]** Discuss why the following statement is true:

$$4\pi\delta^3(\vec{r}) = \vec{\nabla} \cdot \left( \frac{\hat{r}}{r^2} \right)$$

Note consider what happens as  $r \rightarrow 0$  and  $r \rightarrow \infty$ .

**4: Rydberg Atoms can have very large dipole moments [6 pts]:** A Rydberg atom is an atom with a large principal quantum number (e.g.,  $n > 20$ ). Let's say a weird Rydberg Atom has the following charge distribution:

$$\rho(r) = e \delta^3(r) - eA \delta(r - 20a_0)$$

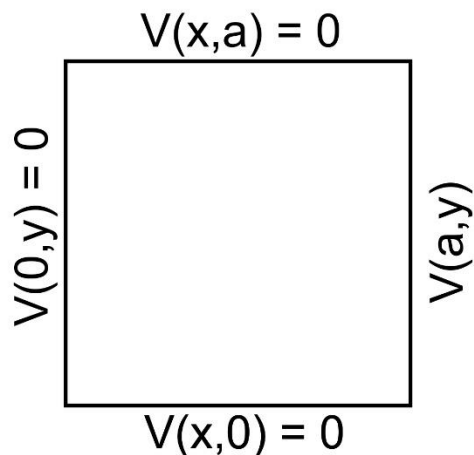
Note,  $a_0$  is the Bohr radius. No Quantum Mechanics is needed to solve this problem.

- (a) [4 pts] Sketch the charge distribution as a function of  $r$ .
- (b) [5 pts] What is  $A$  (make sure to include units)? (Note: the atom is neutral.)
- (c) [8 pts] Find and sketch the radial component of the E-field as a function of radius. Make sure to annotate the graph completely.
- (d) [8 pts] Find and sketch the voltage as a function of radius (assuming  $(\infty) \rightarrow 0$ ). Make sure to annotate the graph completely.
- (e) [5 pts] Would you expect that this system would have a dipole moment that was zero, small, large compared to a normal atom?

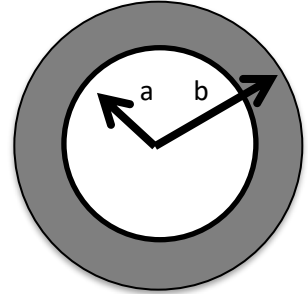
**5: It's the Trick! [6 pts]:** In 2D, the potential on the surface is given in the scenario shown on the right. The potential on the wall on the right has the following dependence on  $y$ .

$$V(a, y) = P_1 \left( \sin \frac{\pi y}{a} \right) + P_0 \left( \sin \left( \frac{3\pi y}{a} \right) \right) + \sin \left( \frac{4\pi y}{a} \right)$$

Find the potential inside the square.



**6: You'd think the bad guys would have learn Death Stars Don't Work [6 pts]:** While constructing the Death Star, there is a large, solid but hollow conducting shell. It has inner radius  $a$ , and outer radius  $b$ . (The inside is completely empty of matter.) Cosmic rays have charged the shell to a total negative charge,  $-q$ . No other charges are around; we're in equilibrium.



- (a) [6 pts] Write out the charge distribution anywhere it's not zero.
- (b) [8 pts] Find and sketch the radial component of the E-field as a function of radius. Make sure to annotate the graph completely.
- (c) [8 pts] Find and sketch the voltage as a function of radius (assuming  $(\infty) \rightarrow 0$ ). Make sure to annotate the graph completely.
- (d) [8 pts] How much electrostatic energy is built up in the system?