

APPENDIX B: THE CUE ASSESSMENT

--- *START ASSESSMENT* ---

Junior-Level Electrostatics Content Quiz

Please fill out the following exam to the best of your ability. This will not count towards your final grade in the course. Do your best to get to all the questions on the test.

When we ask you to explain your answer, please *keep it brief, but clear*. **In most cases, the right answer only gets half credit**, and the rest of the credit is given for your explanation. When asked to do so, be sure to explain your reasoning.

If you don't know an answer, write "I don't know" (instead of leaving it blank).

Name: _____

For each of the following, give a brief outline of the EASIEST method that you would use to solve the problem. Methods used in this class include but are not limited to: Direct Integration, Ampere's Law, Superposition, Gauss' Law, Method of Images, Separation of Variables, and Multipole Expansion.

DO NOT SOLVE the problem, we just want to know:

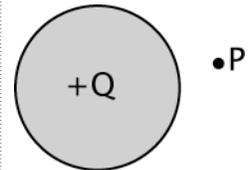
- The general strategy (half credit)
- Why you chose that method (half credit)

EXAMPLE PROBLEM

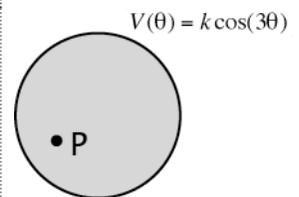
Find the electric field at point P outside a uniformly charged sphere, with total charge +Q.

ANSWER

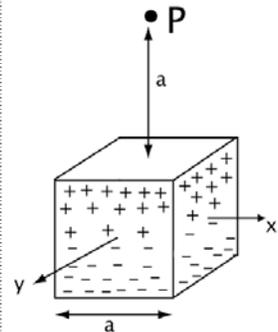
Gauss' Law with a spherical Gaussian surface centered around the origin. Because the E field is symmetric in theta and phi and so is constant on that surface.



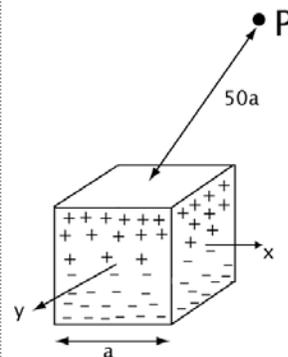
Q1. An insulating sphere with radius R, with a voltage on its surface $V(\theta) = k \cos(3\theta)$. Find E (or V) inside the sphere at point P.



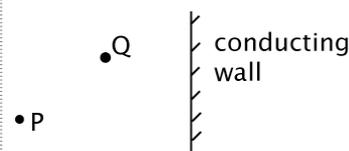
Q2. A solid, neutral non-conducting cube, centered on the origin, with side length "a." It has a charge density that depends on the distance z from the origin, $\rho(z) = kz$, so that the top of the cube is strongly positive and the bottom is strongly negative, as in the figure. Find E (or V) outside, at point P, **on the z-axis**, at a distance a from the cube.



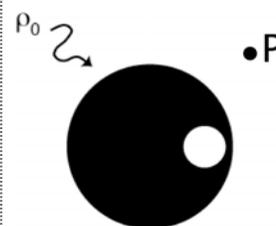
Q3. The same, neutral non-conducting cube as above, with $\rho(z) = kz$, but where P is **off-axis**, at a distance **50a** from the cube.



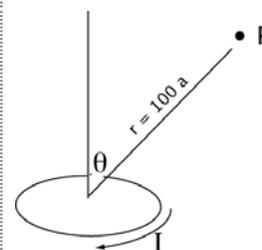
Q4. A grounded conducting plane with a point charge Q at a distance a . Find E (or V) at point P.



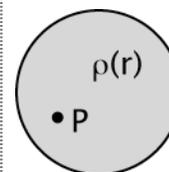
Q5. A charged insulating solid sphere of radius R with a uniform volume charge density ρ_0 , with an off-center spherical cavity carved out of it (see Figure). Find E (or V) at point P, a distance $4R$ from the sphere.



Q6. A current loop of radius a that carries a constant current I . Find B (or A) at point P, **off-axis**, at a distance **$r=100a$** .



Q7. A solid non-conducting sphere, centered on the origin, with a non-uniform charge density that depends on the distance from the origin, $\rho(r) = \rho_0 e^{-r^2/a^2}$ where a is a constant. Find E (or V) inside at point P.

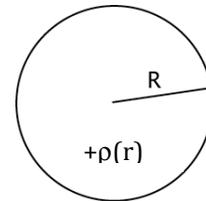


Q8. A **mass** density is given by $\rho(\vec{r}) = m_1 \delta^3(\vec{r} - \vec{r}_1) + m_2 \delta^3(\vec{r} - \vec{r}_2)$, where m_1 and m_2 are constants.

What is the value of $\int_{\text{all space}} \rho(\vec{r}) d\tau$?

What physical situation does this mass density represent?

Q9. You are given a problem involving a non-conducting sphere, centered at the origin. The sphere has a non-uniform, positive and finite volume charge density $\rho(r)$. You notice that another student has set the reference point for V such that $V=0$ at the center of the sphere: $V(r=0)=0$.

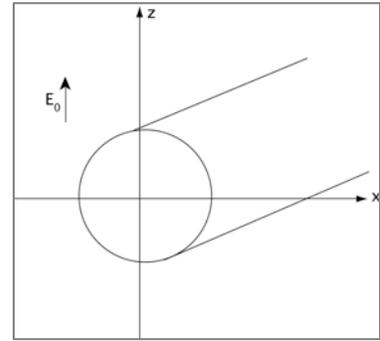


What would $V=0$ at $r=0$ imply about the sign of the potential at $r \rightarrow \infty$?

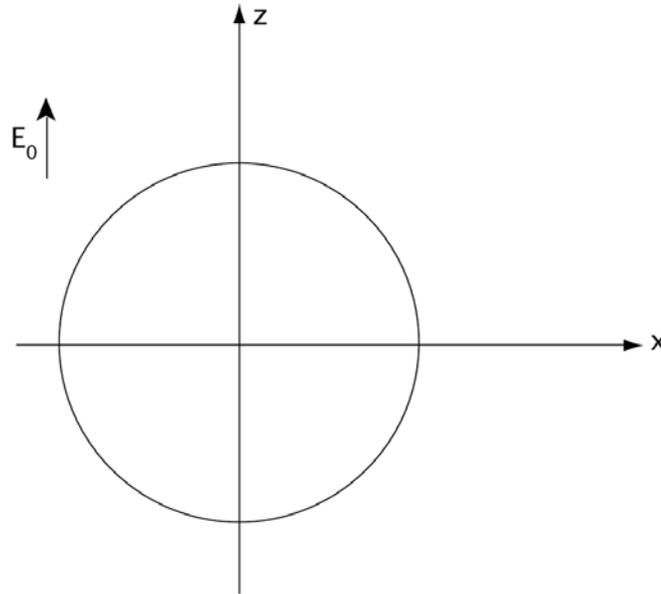
- (a) $V(r \rightarrow \infty)$ is positive (+)
- (b) $V(r \rightarrow \infty)$ is negative (-)
- (c) $V(r \rightarrow \infty)$ is zero
- (d) It depends

Briefly explain your reasoning:

Q10. You are given an infinite solid **conducting** cylinder whose vertical axis runs along the y direction, that is placed in an external electric field, $E_0 \hat{z}$, as in the figure to the right. The cylinder extends infinitely in the $+y$ and $-y$ directions. On the two-dimensional figure below:



- (a) Sketch the induced charge, σ .
- (b) Sketch the electric field everywhere.



Q11. For the conducting cylinder shown above we want to use the method of separation of variables to solve for:

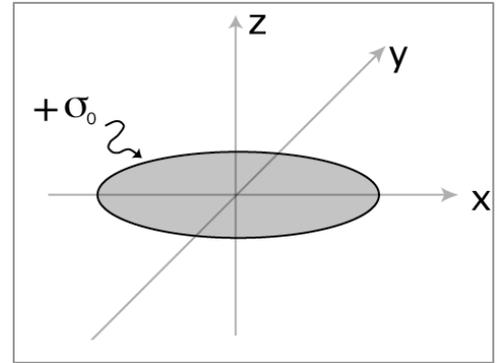
- (a) the potential everywhere and (b) the surface charge σ .

List the boundary conditions on V and/or E at the surface needed to do this.

Do not solve for V , just tell us the boundary conditions on V or E .

Boundary conditions:

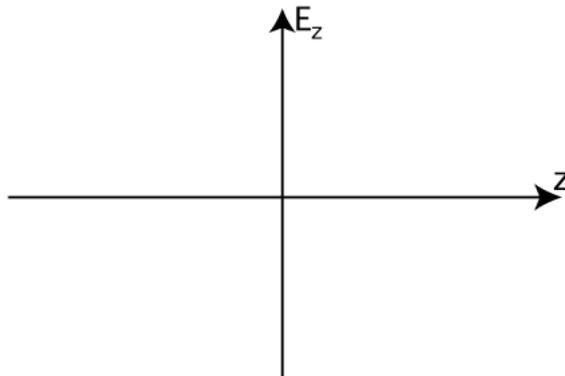
Q12. The following set of problems refer to the uniform flat, infinitely thin disk of radius R carrying uniform positive surface charge density $+\sigma_0$ as in the figure.



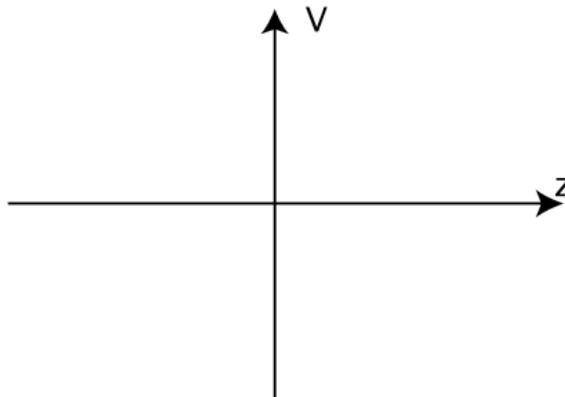
(A) What is the value of the z-component of the electric field (E_z) very near the origin ($z \ll R$)?

(B) How does E_z behave as a function of z as you get very far from the disk ($z \gg R$)?

(C) Draw a qualitative graph of E_z as you move away from the disk, along the z-axis. We are looking for the relative magnitude and sign of E_z as a function of distance from the disk, not field lines. Include both $z > 0$ and $z < 0$ on your graph.



(D) Draw a qualitative graph of V as you move away from the disk, along the z-axis. Include both $z > 0$ and $z < 0$.

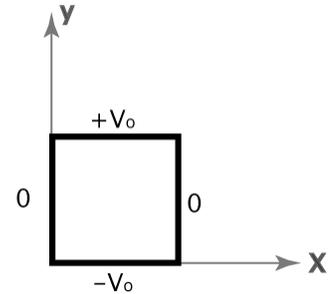


Q13. You are given a 2-D box with potentials specified on the boundary as indicated in the figure to the right. The general solution to Laplace's equation in Cartesian coordinates is

$$V(x,y) = (Ae^{kx} + Be^{-kx}) \cdot (C \sin ky + D \cos ky) \text{ OR}$$

$$V(x,y) = (Ae^{ky} + Be^{-ky}) \cdot (C \sin kx + D \cos kx).$$

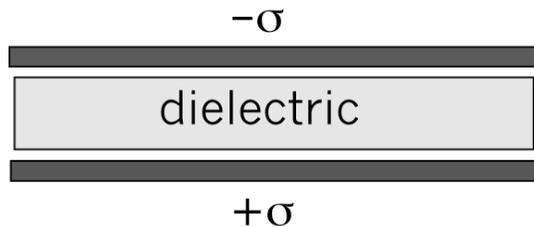
That is, you can choose to associate the *sin* and *cos* with either the *x* or *y* coordinate. **To solve this by separation of variables, which form of the solution should you choose?**



- (a) $V(x,y) = (Ae^{ky} + Be^{-ky}) \cdot (C \sin kx + D \cos kx)$
- (b) $V(x,y) = (Ae^{kx} + Be^{-kx}) \cdot (C \sin ky + D \cos ky)$
- (c) it doesn't matter

Briefly explain your reasoning (no credit for right answer without reasoning) :

Q14. A dielectric is inserted into an isolated infinite parallel plate capacitor, as shown. The dielectric fills the space without quite touching the plates, which are fixed in position.



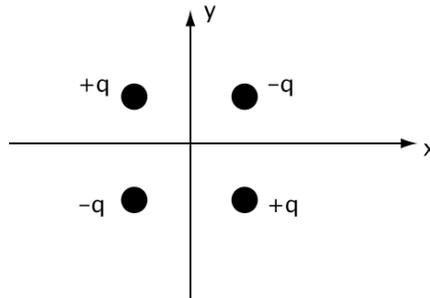
Describe what happens to the dielectric (both in the bulk and at the surfaces) when it is inserted into the capacitor. If a sketch would help, use the space above.

In the limit that the dielectric is infinitely polarizable (i.e. $\chi_e \rightarrow \infty$) what would be the limiting values of the charge(s) and the net electric field in the dielectric?

Q15. Circle **all** of the following boundary conditions that are suitable for solving Laplace's equation for finding $V(r,\theta)$ everywhere due to a charge density σ on a spherical surface of radius R .

- (I) $V_{in}=V_{out}$ at $r=R$
 (II) $\vec{E}_{in} = \vec{E}_{out}$ at $r=R$
 (III) $E_{in}^{\perp} - E_{out}^{\perp} = -\sigma/\epsilon_0$ at $r=R$
 (IV) $E_{in}^{\parallel} - E_{out}^{\parallel} = -\sigma/\epsilon_0$ at $r=R$
-

Q16. You are given the following charge distribution made of 4 point charges, each located a distance "a" from the x- and y-axis.

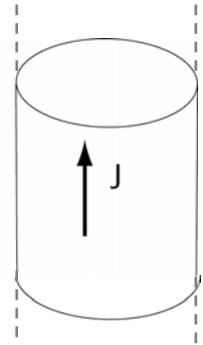


The dipole moment of this distribution is:

- (a) Zero
 (b) Non-zero
 (c) Not sure

Briefly explain your reasoning:

Q17. Consider an infinite non-magnetizable cylinder with a uniform volume current density J .



Where is the B field maximum? Explain how to determine this.

How seriously did you just take this diagnostic exam?

- (a) I pretty much blew it off, didn't think much about a lot of the answers.
- (b) I took it sort of seriously, but when I didn't know an answer I didn't think very hard about it.
- (c) I took it seriously, and thought about my answers.

If you imagine getting a letter grade on the portion of this test that you were able to complete within the time limit, what do you think that grade would be? ____

Any other comments?