Phys 110, Spring 2018,

Exam 1 review questions (taken from CU Boulder)

The questions are very Griffiths-related, so in that sense they are great for this purpose. In terms of a solid review for us: most of what's missing is the pure math stuff. So you could expect more pure math questions on our exam.

We start with some short questions. Don't spend a lot of time on these – if you don't know how to do them, move on – they don't require a lot of calculating.

1.) For each statement, circle True or False. You do not need to explain your reasoning. *(2 pt each)*

i) If the total charge enclosed inside a Gaussian surface is zero, then **E** everywhere on the Gaussian surface must be zero.

Circle one: True, False

ii) A spherical region (radius R, centered on the origin) has electric field **E**(**r**)=0 throughout. The voltage V(r) must also vanish throughout that region.

Circle one: True, False

iii) A spherical region (radius R, centered on the origin) has voltage V(**r**) = 0 throughout. The Electric field **E**(**r**) must also vanish throughout that region.

Circle one: True, False

iv) If you have a point charge at rest at the point (x_0,y_0,z_0), and no other charges anywhere, then $\nabla\cdot\vec{\mathbf{E}}=0$ everywhere in all space. *(I borrowed this question from somewhere else, it might be trickier for us, but we have seen this.)*

Circle one: True, False

v) If you have a point charge at rest at the point (x_0,y_0,z_0), and no other charges anywhere, then $\nabla\times\vec{\mathbf{E}}=0$ everywhere in all space.

Circle one: True, False

2.)

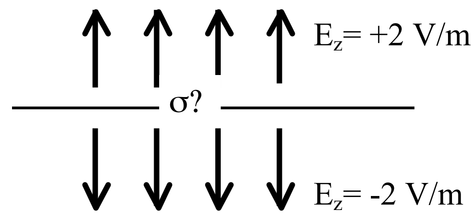
i) *(3 pts)* The figure shows an edge-on view of a surface (in the middle) with some surface charge density σ on it.

The E-field just above the surface is $\vec{\mathbf{E}} = +2\ \hat{z}\ \ [\mathrm{N/C}]$.

Just below the surface it is $\vec{\mathbf{E}} = -2\ \hat{z}\ \ [\mathrm{N/C}]$.

What is the charge density σ on the surface?

(An expression is fine, you don't need to pull out a calculator)



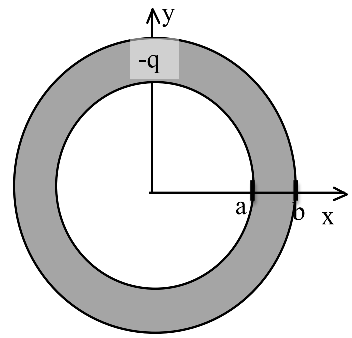
ii) *(3 pts)* Suppose $\vec{\mathbf{E}}(x,y,z) = \dfrac{c}{\varepsilon_0}\, x\, \hat{x}$ in some limited region of space.

(c is a constant, and ε_0 =1/4πk is the usual fundamental constant in Coulomb's law)

What charge density ρ(x,y,z) must be present in the region?

The next questions require a little more work, but still don't need a lot by way of "calculating".

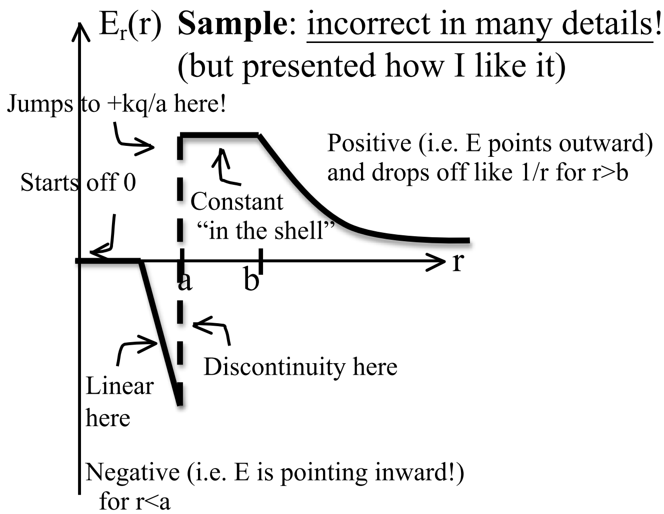
3.) While constructing the Death Star, there is a large, solid but hollow conducting shell.
It has inner radius a, and outer radius b.
(The inside is completely empty of matter)
Cosmic rays have charged the shell to a total **negative** charge, $-q$.
No other charges are around; we're in equilibrium.

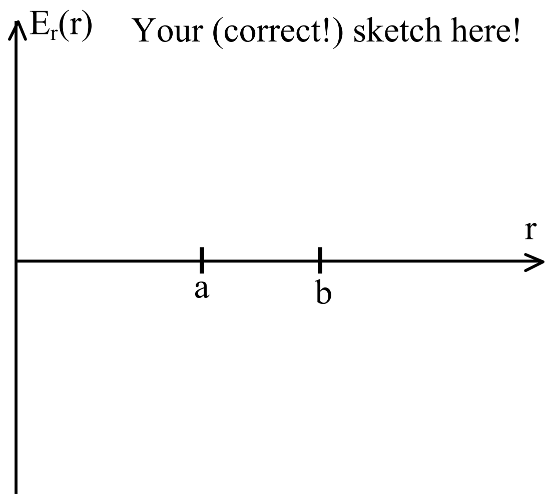


a) *(3 pts)* **Below, write quantitative formula(s) for the equilibrium charge distribution anywhere it's nonzero.**

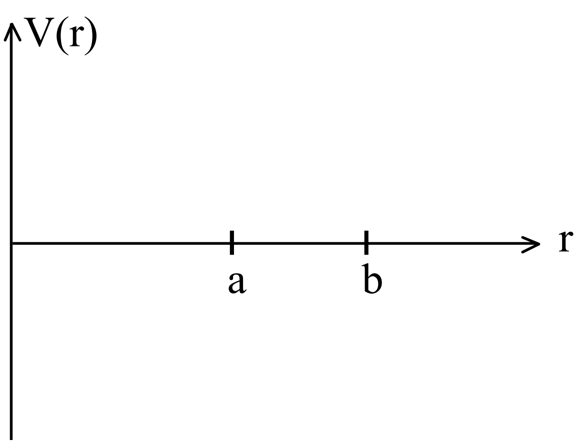
Hint: charge flows freely around a conductor until there is no more force or the charges (meaning no field). Given that: what do you think the distribution of charges will look like?

b) *(6 pts)* Sketch the radial component of the E-field as a function of radius.
If you know values (e.g. maxima), give a formula for them. ***Use my "sample" as a guide to the sorts of things I'm looking for, help me understand what you know!***



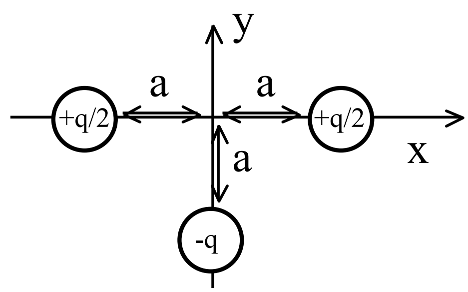


c) *(6 pts) Sketch* voltage as a function of radius (assuming $V(\infty)=0$)
Again, show briefly but clearly all features, be quantitative when you can, just like you did above



4.) A very crude model for a neutral water molecule is shown in the figure, a negative “O” and two positive “H’s”. *The geometry has been simplified to make the math easier.* As usual, assume V(∞)=0.

a) *(4 pts)* What is the Electric field at the origin (the point midway between the two positive hydrogens)?



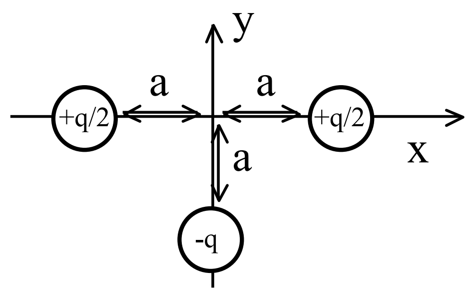
b) *(2 pts)* What is the electric potential at the origin?

b-ii) Could you have integrated over the *E*-field to get *V*? Why or why not?

c) *(4 pts)* If you place a positive test charge (q’) at the origin, what is the force on the test charge (q’)?

5.) (Repeat for a different (harder to calculate) location)
A very crude model for a neutral water molecule is shown in the figure, a negative "O" and two positive "H's". *The geometry has been simplified to make the math easier.*
As usual, assume $V(\infty)=0$.

a) *(4 pts)* What is the Electric field at a height y above the origin?



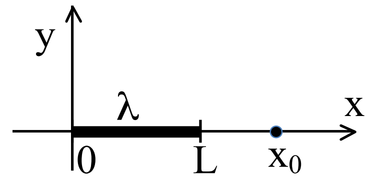
b) *(2 pts)* What is the electric potential at a height y above the origin?

b-ii) Could you have integrated over the E-field to get V? Why or why not?

c) *(4 pts)* If you place a positive test charge (q') at that same point, what is the force on the test charge (q')?

And now, some computational problems.

6.) You have a short (finite!) uniform line charge λ which runs from x=0 to x=+L, sitting on the x-axis. There are no other charges anywhere.

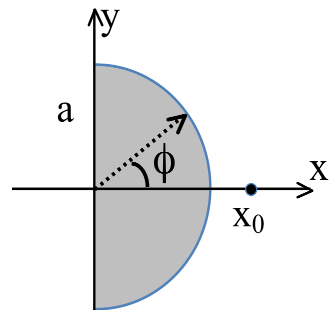


a) (*9 pts)* Calculate the electric potential $V(x_o,0,0)$ at some given arbitrary point "x_0" on the positive x-axis (*assume $x_0>L$, i.e. we are past the end of the charged rod*)
Your final answer should be in terms of just the givens: x_0, λ, and L
(As usual, please choose $V(\infty)=0$)
Hint: Just like you can calculate E by chopping up the charge distribution into infinitesimally small chunks, dq, you can calculate V the same way! Give it a try. Or, you can calculate E first, then use that to get V. If you have time, do both!

b-i) *(3 pts)* Without doing any calculations, what do you expect for the limiting behavior of $V(x_0,0,0)$ as $x_0 \to \infty$? (Please do not just say "it goes to 0", how should it go to zero?)

b-ii) *(3 pts)* Use your result from part a to verify that the limiting behavior matches your intuition.

7.) You have a flat insulating semi-circular (half) disk in the x-y plane: radius a. It is NOT a conductor!
(It's like a dvd disk that has been chopped in half.)
It has a *nonuniform* charge density $\sigma = \sigma_0 \cos(\phi)$ (where ϕ is the usual azimuthal angle in the x-y plane, as shown, and $\sigma_0 > 0$.)



i) *(6 pts)* Compute the total charge on this disk
(in terms of givens: a, and σ_0)

ii) *(2 pts)* Consider the point (shown) on the +x axis (a given distance x_0 from the origin) Do any components of the field $\mathbf{E}(x_0,0,0)$ at this point vanish "by inspection"? Why?

iii) *(9 pts)* Find an expression for the x-component of the E-field, $E_x(x_0,0,0)$ (at this given point on the x-axis.) **Note**!! Your expression will involve integrals which you cannot do analytically - stop when you have a mathematical expression which could in principle be evaluated by a computer program (or maybe a strong math major ☺)
That means that all integrals need to be written out clearly and neatly:
- clearly label all variables of integration (don't be sloppy here, I need to follow!)
- clearly label all LIMITS of integration too. And simplify as much as possible.