✯ TUTORIAL 2✯

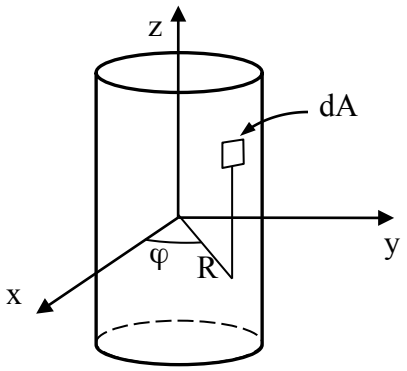
SLAC LIGHTNING STRIKE!

Part 1 – SLAC Lightning Strike

SLAC (Stanford Linear Accelerator Center) is where quarks (including the charm quark), and the tauon (like a heavier electron) were discovered. It is now used for other research purposes! Charged particles are accelerated inside a long metal cylindrical pipe, which is 2 miles long and has a radius R = 6 cm. All the air is pumped out of this pipe, known as the "beam line."

One afternoon, the beam line is struck by lightning, which gives it a uniform surface charge density σ. After the lightning strike, Stanford physicists want to start accelerating particles in the beam line, but they are concerned that the charge density might affect the beam particles, causing them to crash into the wall of the pipe and burn a hole through it. Air and dirt would rush into the empty pipe causing months of expensive delay. You will investigate whether the surface charge of the beam line could affect the beam particles.

i. First, what is the infinitesimal area, d**A**, of a small patch on a cylindrical shell centered on the z-axis? Assuming you use this d**A** in a surface integral over a closed surface, give the vector direction of d**A**.



ii. What direction does the E-field point at all points in space? *Explain in detail* how you know. (i.e. simply stating symmetry is not enough: how does symmetry tell us this?)

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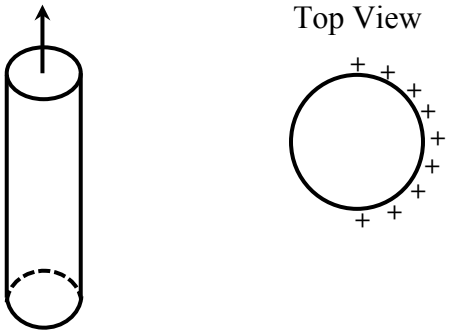
iii. Use Gauss's Law to find the E-field at all points in space.

iv. Does the charge σ on the beam line affect the particles being accelerated inside it? Could it affect the electronic equipment outside the tunnel?

You are in a freshman physics course and are given a long glass rod and a piece of silk. You rub the silk cloth along the length of the rod, but only on one side, until that side has a uniform surface charge distribution σ. Now you would like to calculate the electric field from the rod.



Does Gauss' Law apply in this case? Can you use Gauss' Law to calculate the electric field from the rod? If so, calculate it. If not, explain why not.

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Part 2 - Divergence and Delta Functions

i. Determine a purely mathematical expression for the volume charge density, ρ, of the beam line (the beam line is a hollow metal cylinder with charge σ).

ii. Check your answer by integrating to find the total charge for a length L of beam line. (Are the units correct?)

iii. What are the units of your delta function in (i.)? (This is another way of checking your answer to (i.), so don't *only* use your answer to (i.) to check the units.)

iv. You have found that when charged, SLAC's beam line produces an E-field. Considering all space, describe where is this E-field's divergence zero and where is it non-zero? Can you now write one mathematical expression which says the same thing?

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