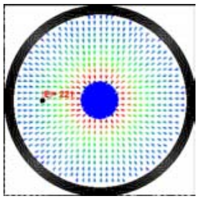
Worksheet for Exploration 26.5: Capacitance of Concentric Cylinders



Wait for the calculation to finish. This animation shows a coaxial capacitor with cylindrical geometry: a very long cylinder (extending into and out of the page) in the center surrounded by a very long cylindrical shell **(position is given in centimeters, electric field strength is given in N/C, and electric potential is given in volts)**. The outside shell is grounded while the inside shell is at 10 V. You can click-drag to measure the voltage at any position.

a. Use Gauss's law to show that the magnitude of the radial electric field between the two conductors for a cylindrical coaxial capacitor of length L is $E = Q/2\pi rL\varepsilon_0 = 2kQ/(rL)$, where Q is the total charge on the inside (or outside) conductor and r is the distance from the center.
   i. Your Gaussian surface should lie centered around the coax cable with the radius r being different from the radius of the inner or outer surfaces. Start with Gauss's law and justify each step you take.

b. If L = 1 m, measure the electric field in the region between the two conductors and determine the charge on the inside (and outside) conductor.

E=________ r=________ Q=________

c. Use $V = -\int \mathbf{E} \cdot d\mathbf{r}$ to show that the potential at any point between the two conductors is $V = (Q/2\pi L\varepsilon_0) \ln(b/r) = (2kQ/L) \ln(b/r)$ where b is the radius of the outer conductor.
   i. The outer surface is used as the reference potential where the potential is zero.

d. Given that the potential difference between the two cylinders is 10 V, verify your answer to (b) and find the charge on each conductor.

e. Given, then, that the potential difference between the two conductors is $V = (Q/2\pi L\varepsilon_0)\ \ln(b/a) = (2Qk/L)\ \ln(b/a)$, (b is the radius of the outer shell and a is the radius of the inner cylinder) show that the capacitance of this capacitor is $(2\pi L\varepsilon_0)/\ \ln(b/a) = (L/2k)*(1/\ \ln(b/a))$.
   i. This is a capacitance for a given length L.
   ii. You should also consider some limiting cases here and discuss. What happens as b approaches a? And what happens as b>>a?

f. What is the capacitance/unit length (numerical value) of this capacitor?