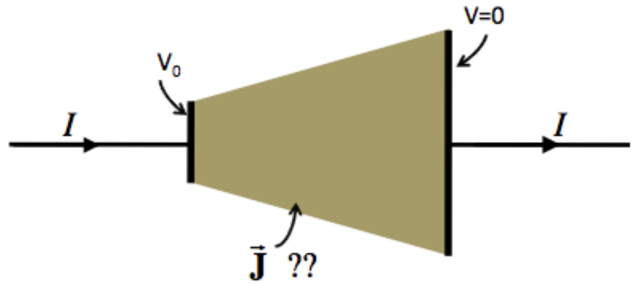
A. A <u>steady</u> current I flows through conducting wires that are connected to two metal disks that cap the ends of a cone-shaped resistor (made from a material with uniform conductivity σ). There is a potential difference V_0 between the two metal end caps.



In the figure, predict (sketch) the E-field lines inside the resistor.

Don't spend much time on this, your first intuition is fine for now!

i) When there is a steady current flowing, is the time-derivative of the charge density $\partial\rho/\partial t$ *inside* the resistor *zero* or *non-zero*?

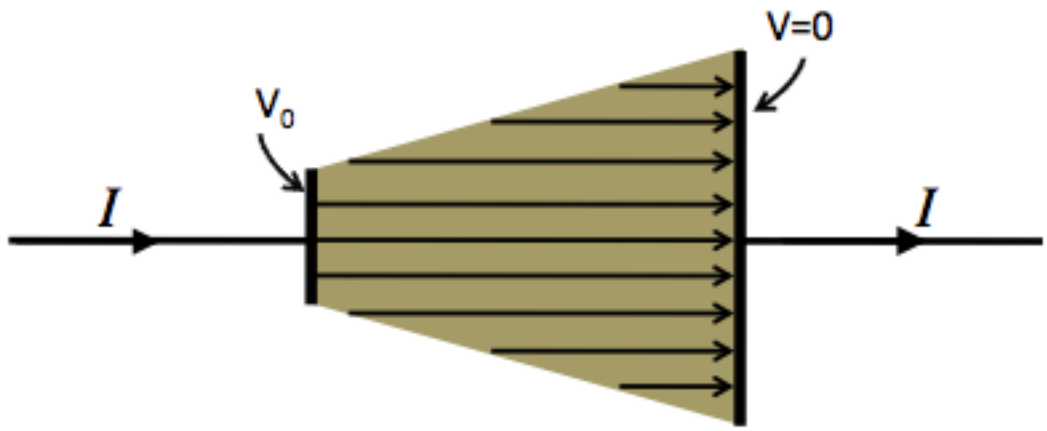
ii) Considering the continuity equation: $\nabla\cdot\mathbf{J} = -\partial\rho/\partial t$, is the divergence of the current density *inside* the resistor *zero* or *non-zero*?

iii) Considering Ohm's law: $\mathbf{J} = \sigma\mathbf{E}$, is the divergence of the electric field *inside* the resistor *zero* or *non-zero*?

iv) Considering Gauss' law: $\nabla\cdot\mathbf{E} = \rho/\varepsilon_0$, is the volume charge density *inside* the resistor *zero* or *non-zero*?

Refer back to all the conclusions on this page for the next parts!

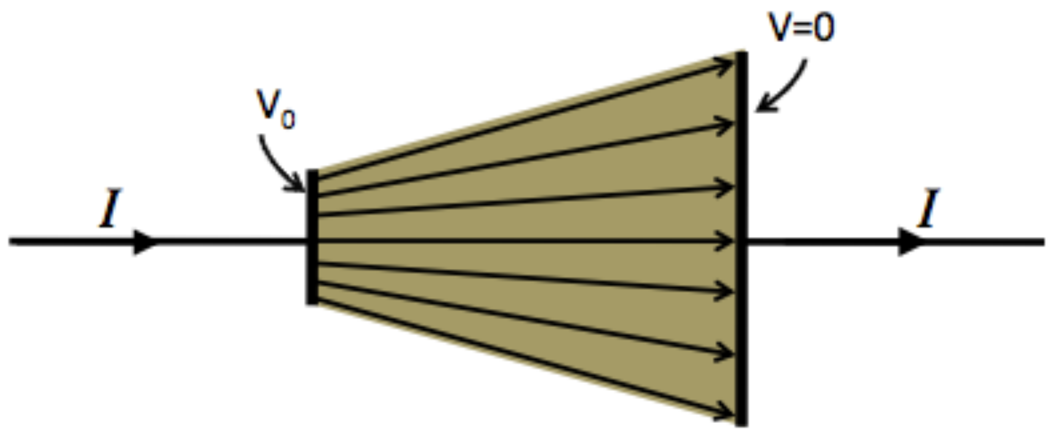
Is there anything about the sketch you started off with that you want to fix up, yet? Again, don't spend too much time on this, we'll come back to it.



B. For this same situation, the diagram now shows one way that a student has drawn the electric field lines inside the resistor.

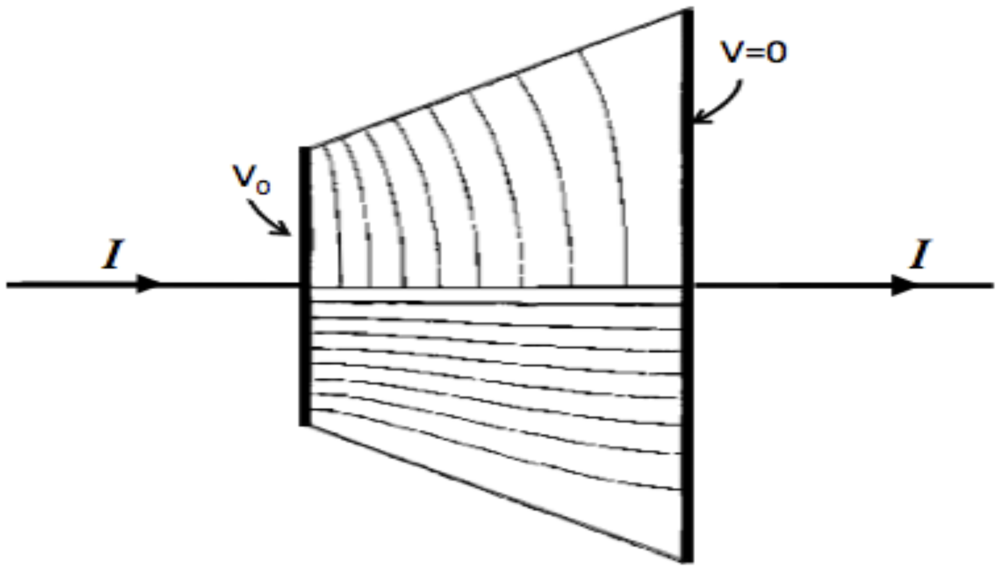
Which aspects of this drawing are correct, and which are incorrect? List as many as you can *in favor* of this drawing, and as many as you can *against* it.

[Hint: Try to answer for yourself questions like the following: Is charge conserved? Is the total current flowing constant? Is the divergence of the electric field inside the resistor correct? Are the boundary conditions satisfied? Are there other things that need to be considered?]



C. The diagram now shows another way that a student has drawn the electric field lines inside the resistor.

Which aspects of this drawing are correct, and which are incorrect? List as many as you can *in favor* of this drawing, and as many as you can *against* it.



D. The diagram now shows the correct *equipotential* lines (upper half) and correct *E-field* lines (lower half) inside this cone-shaped resistor.[1]

Explain how both of these sets of lines are consistent with the conditions that needed to be satisfied by the electric field inside the resistor, as you discussed on the previous pages.

Challenge Question: What can you conclude about the magnitude of the electric field as you get closer and closer to the bottom right-hand corner of the resistor? Explain your answer in terms of boundary conditions.

[1] Credit to J. D. Romano and R. H. Price for finding this solution numerically.