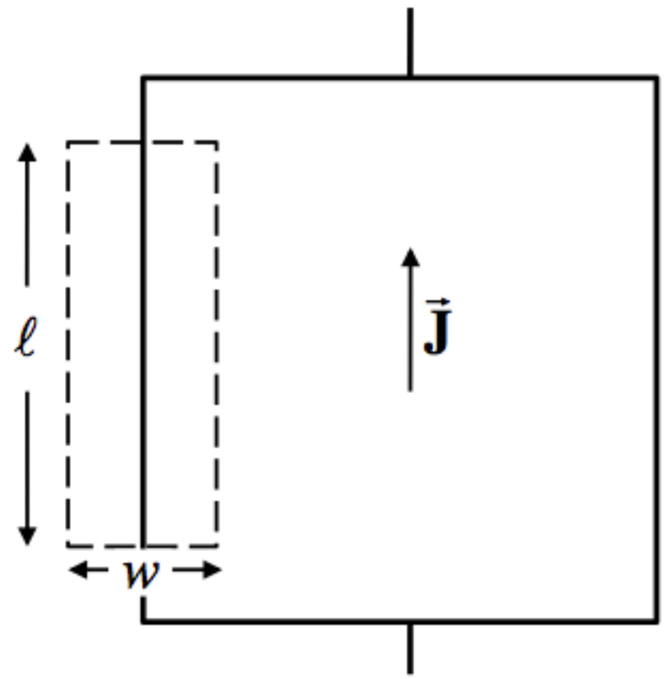
B. Consider an Amperian loop (dashed lines) with length ℓ and width w that straddles the surface of the resistor.

Recall Faraday's Law:

$$\oint \vec{\mathbf{E}} \cdot d\vec{\ell} = -\frac{d}{dt}\iint \vec{\mathbf{B}} \cdot d\vec{\mathbf{a}}$$

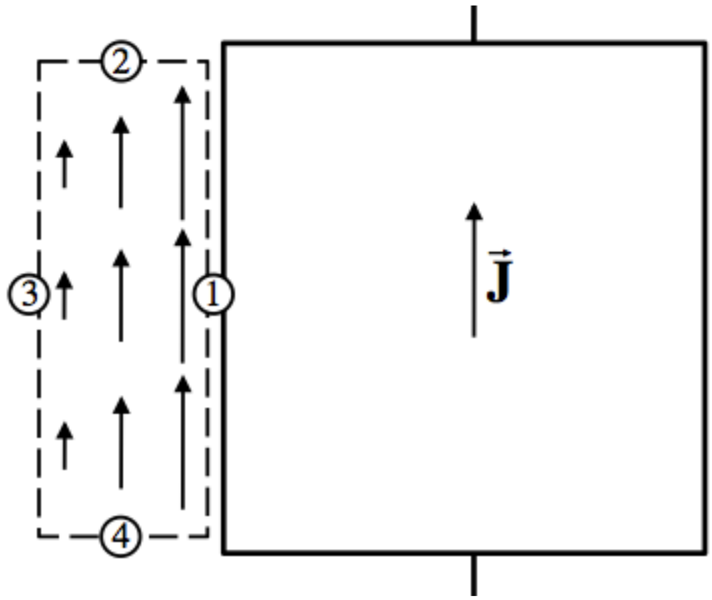


Is the line integral of the electric field along this closed Amperian loop *positive*, *negative* or *zero*?

Briefly explain your reasoning.

Imagine we let $w \to 0$ while keeping the loop centered on the wall of the resistor. In this situation, is the *parallel* component of the electric field outside the resistor *zero* or *nonzero*? Briefly explain your reasoning.

C. The <u>total</u> electric field must diminish as we move away from the resistor. The arrows inside the dashed region on the left represent the magnitude and direction of the <u>parallel</u> component of the electric field outside the resistor. Consider a line integral of the electric field $\oint \vec{\mathbf{E}} \cdot d\vec{\ell}$ in the **counter-clockwise** direction. $[1 \rightarrow 2 \rightarrow 3 \rightarrow 4]$



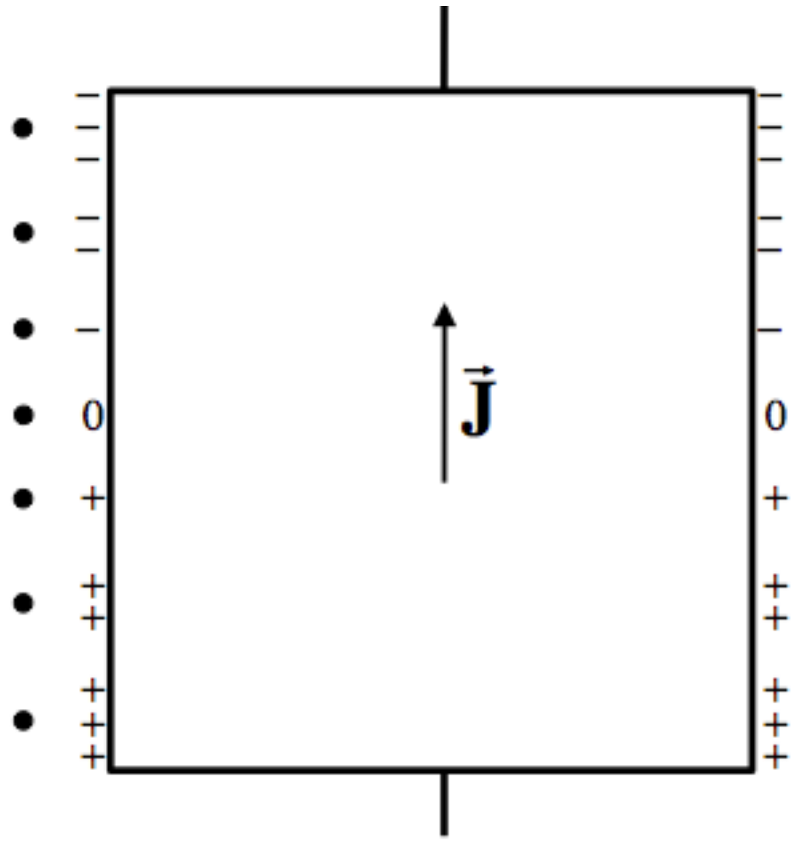
Is the contribution to the line integral from the parts of the loop that are **parallel** to the surface (1 & 3 only) *positive*, *negative* or *zero*?

Is the contribution to the line integral from the parts of the loop that are **perpendicular** to the surface (2 & 4 only) *positive*, *negative* or *zero*?

Indicate in the diagram the direction of the <u>perpendicular</u> component of the electric field $\mathbf{E}^{\perp}$ along parts 2 & 4 of the loop. Assume that both parts contribute equally to the line integral.

Is the volume charge density inside the resistor *positive*, *negative* or *zero?* Where are the charges located that are responsible for the perpendicular components of the electric field outside the resistor?

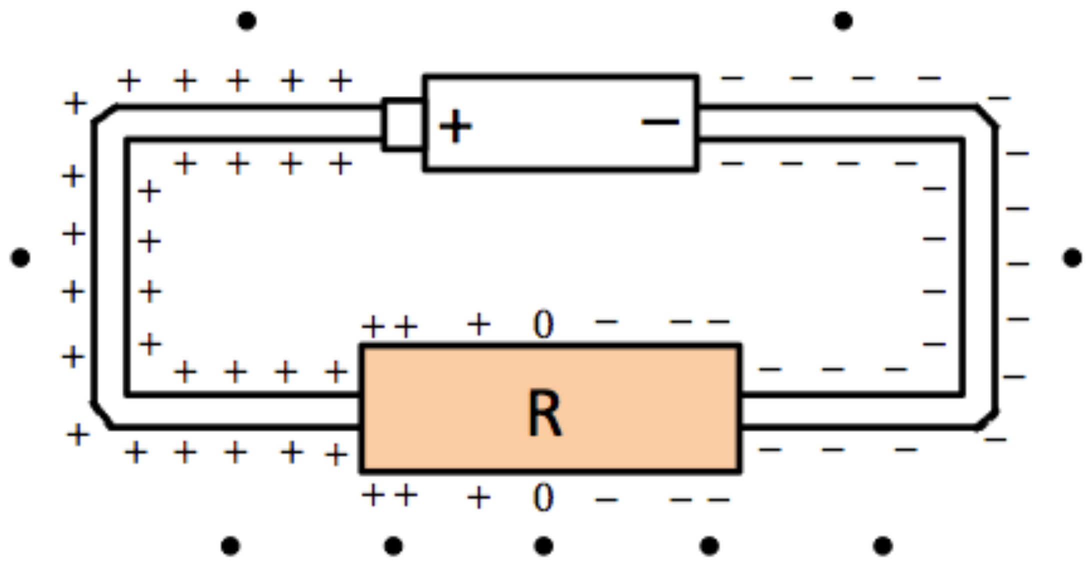
D. Suppose the steady-state surface charge on the resistor is distributed as shown in the diagram. The surface charge density varies smoothly from positive at the bottom to negative to negative at the top.



Sketch the magnitude and direction of just the <u>perpendicular</u> component of the electric field $\mathbf{E}^{\perp}$ at the points indicated just outside and to the <u>left</u> of the resistor (circular dots).

Suppose the resistor were *instead* an ideal conductor ($\sigma \to \infty$). Would the <u>parallel</u> component of the electric field *just outside* this ideal conductor be *zero* or *nonzero*? [Hint: What happens to the electric field <u>inside</u> the material if the current density $\vec{\mathbf{J}} = \sigma\vec{\mathbf{E}}$ remains finite as $\sigma \to \infty$?]

E. The diagram below depicts <u>ideal</u> <u>conducting</u> <u>wires</u> ($\sigma \to \infty$) that connect a battery with a resistor $\mathbf{R}$. The surface charge on the ideal conducting wires is roughly uniform, and varies smoothly from positive to negative on the surface of the resistor. [The diagram is schematic, so assume the nine circular dots shown in the diagram are lying just outside the circuit elements – the fields at each of the dots are not influenced by charges or currents in other parts of the circuit.]



In the diagram above, sketch the direction of the <u>total</u> electric field $\vec{\mathbf{E}}$ at each of the *nine* points indicated (circular dots).

At the same nine points, indicate the direction of the magnetic field $\vec{\mathbf{B}}$ due to the current flowing through the circuit.

Now draw the direction of the Poynting vector $\vec{\mathbf{S}}$ at each of these points.

From this information, describe in words how energy is flowing from the battery to the resistor. Where is the energy flowing, and in what direction(s)? Is energy flowing through the ideal conducting wires?