Conductors in Electrostatics

a summary of key ideas

Electric Flux and Potential

I. Electric Flux
- flux defined
- Gauss's Law

II. Electric Potential
- work and energy of charge
- potential defined
- potential of discrete charge(s)
- potential of charge distributions
- field related to potential

III. Conductors

	The student will be able to:	HW:
1	Define and apply the concept of electric flux and solve related problems.	✓ 1 – 5
2	State and apply Gauss's Law and solve related problems using Gaussian surfaces.	✓ 6 – 17
3	Calculate work and potential energy for discrete charges and solve related problems including work to assemble or disassemble.	✓ 18 – 25
4	Define and apply the concept of electric potential and solve related problems for a discrete set of point charges and/or a continuous charge distribution.	✓ 26 – 32
5	Use the electric field to determine potential or potential difference and solve related problems.	✓ 33 – 36
6	Use potential to determine electric field and solve related problems.	✓ 37 – 39
7	State the properties of conductors in electrostatic equilibrium and solve related problems.	40 – 46

Key Ideas

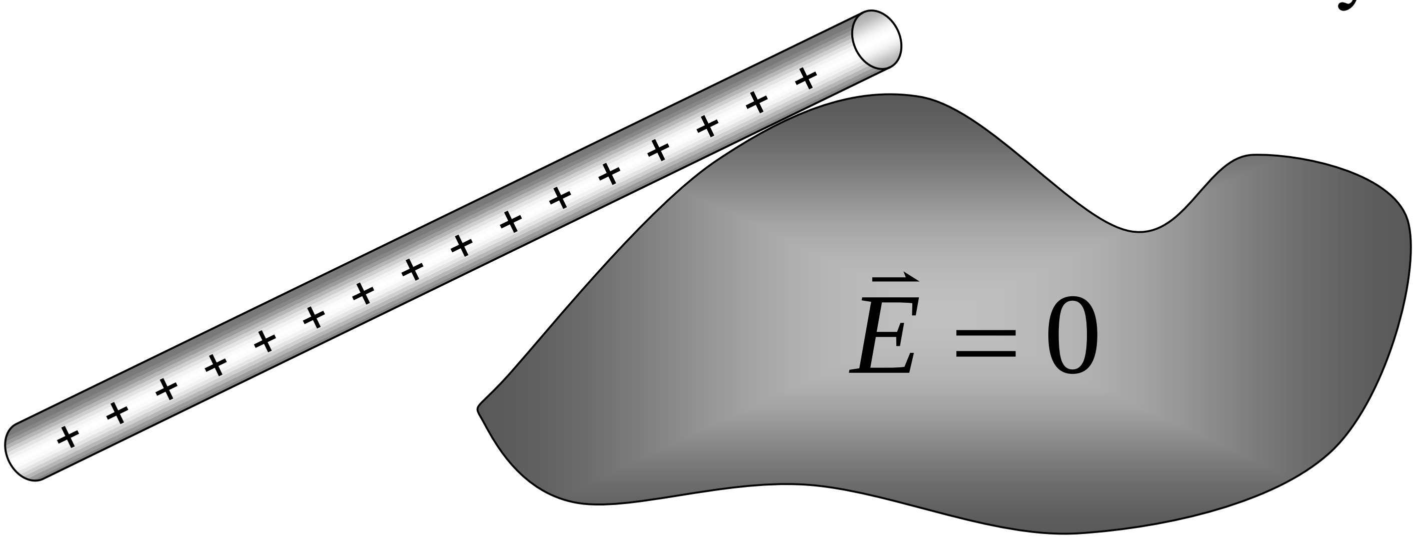
- The defining property of a conductor is that charge can move freely through it. This is true of metals like copper, gold, silver, aluminum, etc.
- When a conductor receives a net charge the charge can move through the conductor and take on a certain distribution or arrangement.
- When electrostatic equilibrium is reached, the conductor will exhibit certain properties...

Conductors in Electrostatic Equilibrium

1. The electric field anywhere inside a conductor is zero.
2. Any excess charge on a conductor resides entirely on its surface.
3. The electric field is perpendicular to the surface at all points.
4. At any point just above the surface the field has magnitude σ/ε_o.
5. The surface is an equipotential surface.
6. The interior is the same potential as the surface.

Consider this arbitrary conductor that is charged by a positive glass rod ...

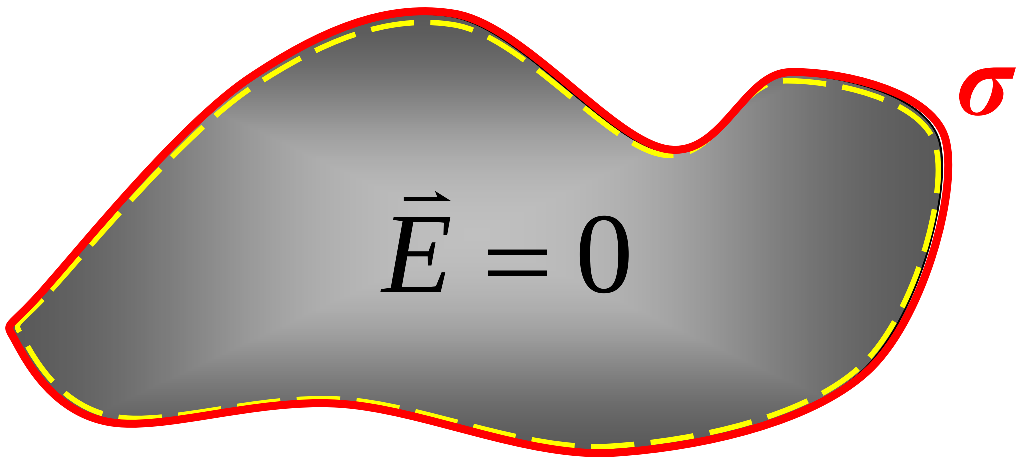
There cannot be an electric field anywhere in the conductor's interior. But why not?



Because if there *were* an electric field then charge would move (freely) through the conductor, which contradicts the assumption of electro*statics*.

Now consider a Gaussian surface placed inside the conductor *just below* the surface.

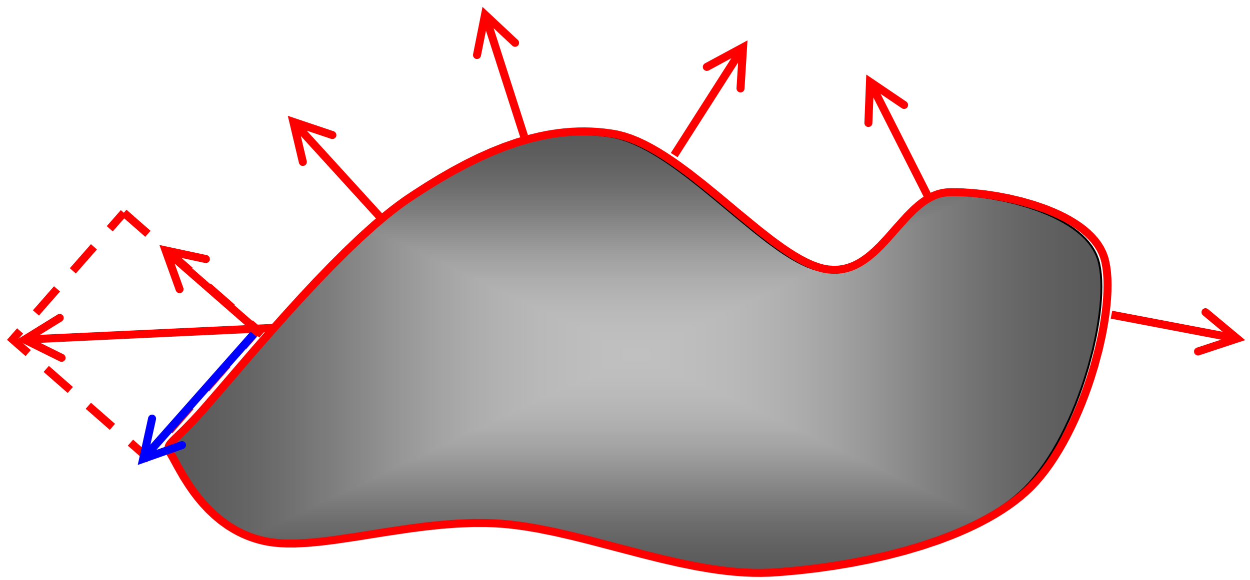
What is the flux through this surface and what does this imply?



The flux is zero and therefore, according to Gauss's Law, there can be no net charge *within* the conductor. All net charge is distributed across the surface.

The electric field just outside of the conductor is *normal* to the surface at all points.

Why must this be?

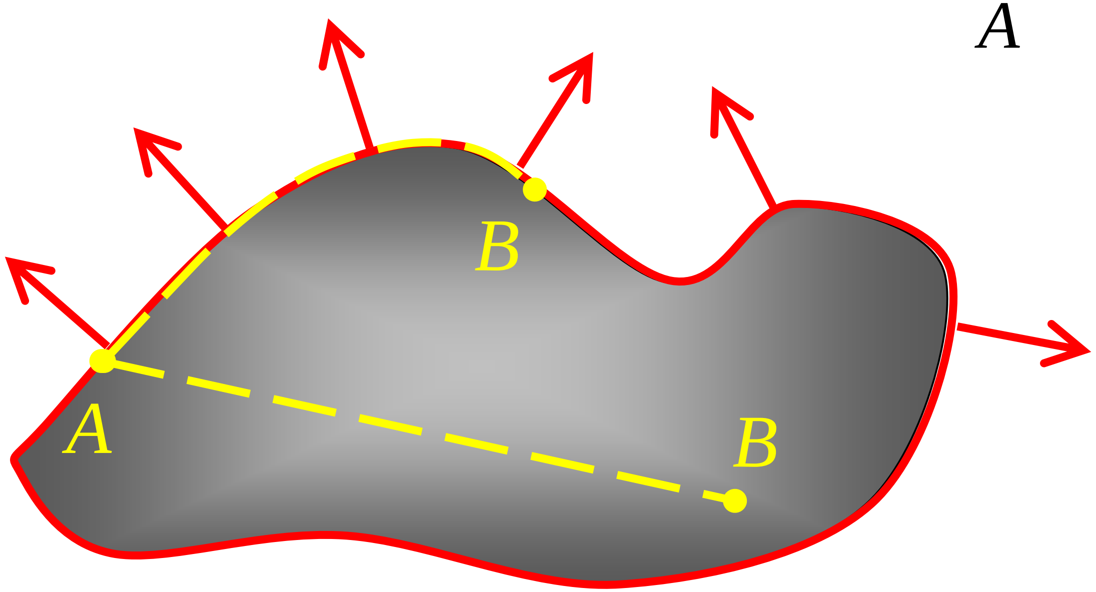


If it were *not* perpendicular then there would be a component directed along the surface which would make the charge move – once again contradicting the assumption of electro*statics*.

The entire conductor and its surface are at the same potential.

Why must this be?

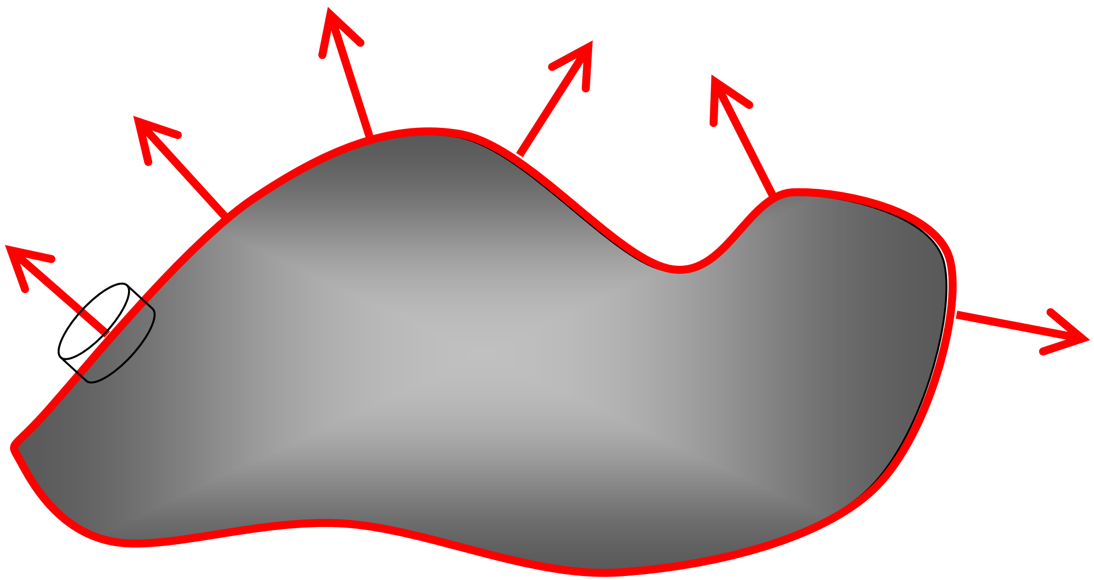
$$V_B - V_A = \int_A^B \vec{E} \cdot d\vec{l}$$



The work done by the field along any path is zero. Therefore $V_B - V_A = 0$.

At any point just above the surface the field has magnitude σ/ε_o.

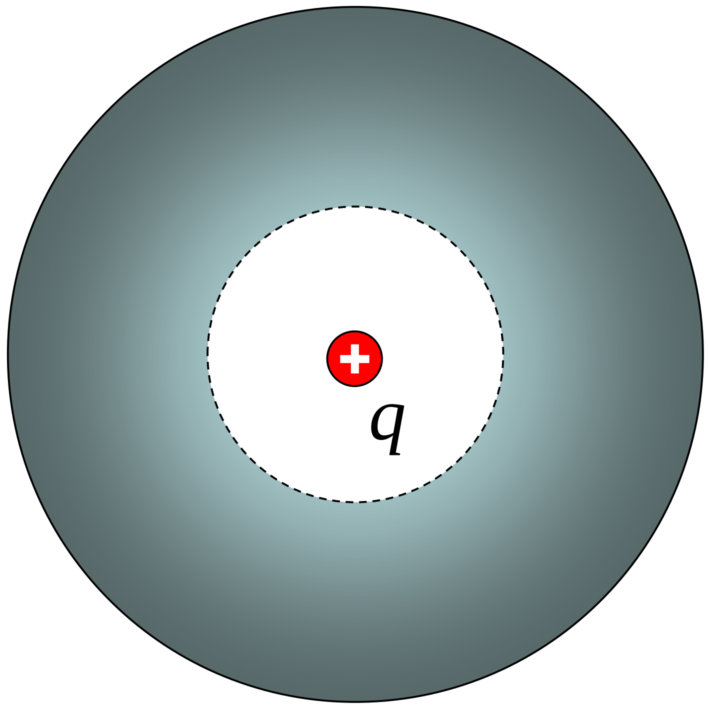
Why must this be?



Apply Gauss's Law to a tiny "pill box" that contains a small patch of the surface.

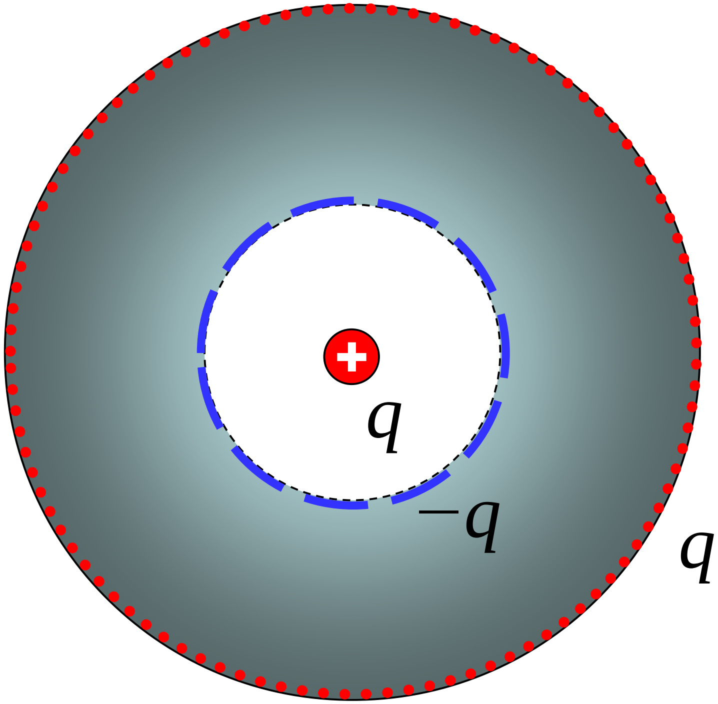
Suppose a conductor has a hollow cavity within it.

A positive point charge q is placed inside it.

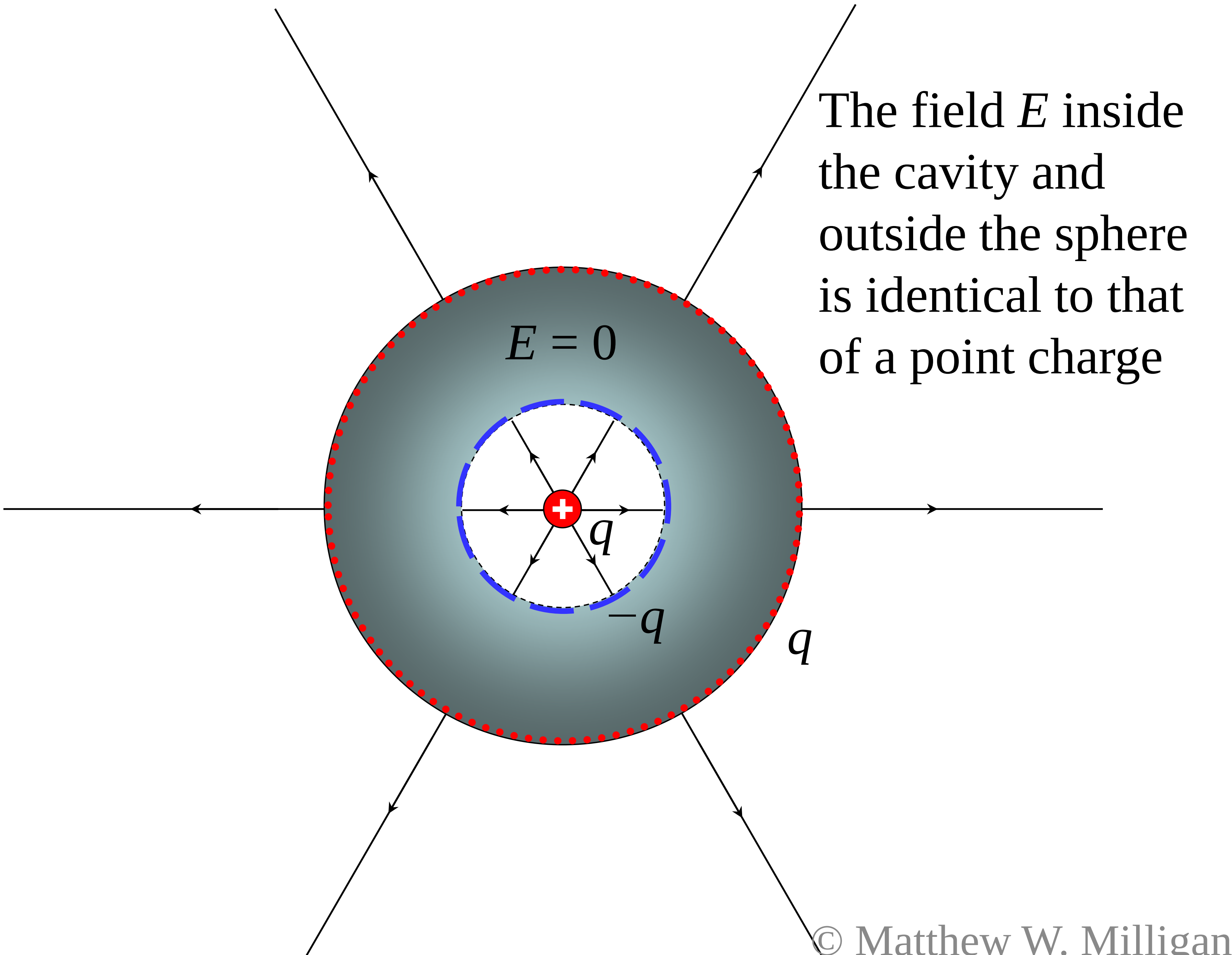


What happens in the conductor?

Surface charges of net amounts $-q$ and q will be induced on the surface of the cavity and on the exterior surface of the conductor.



What will the field look like?


The field E inside the cavity and outside the sphere is identical to that of a point charge
$E = 0$
q
$-q$
q
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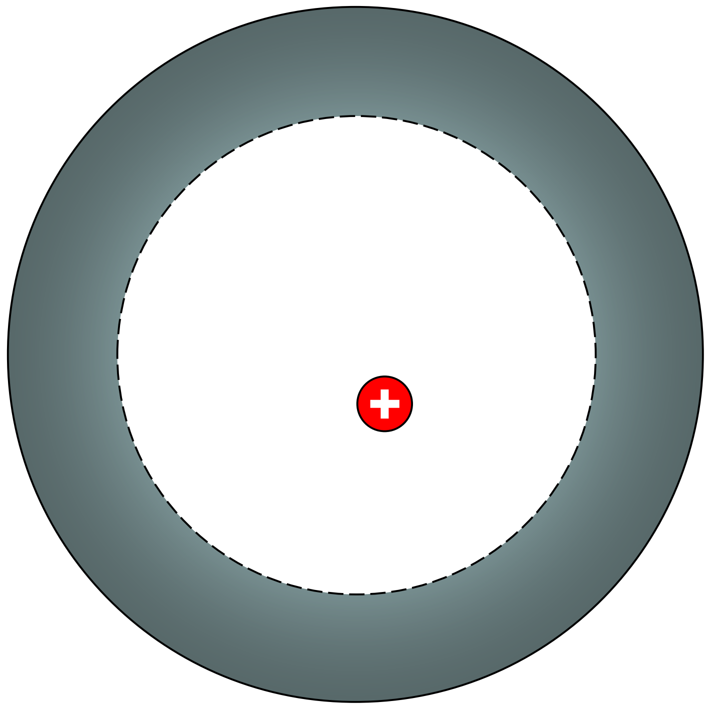
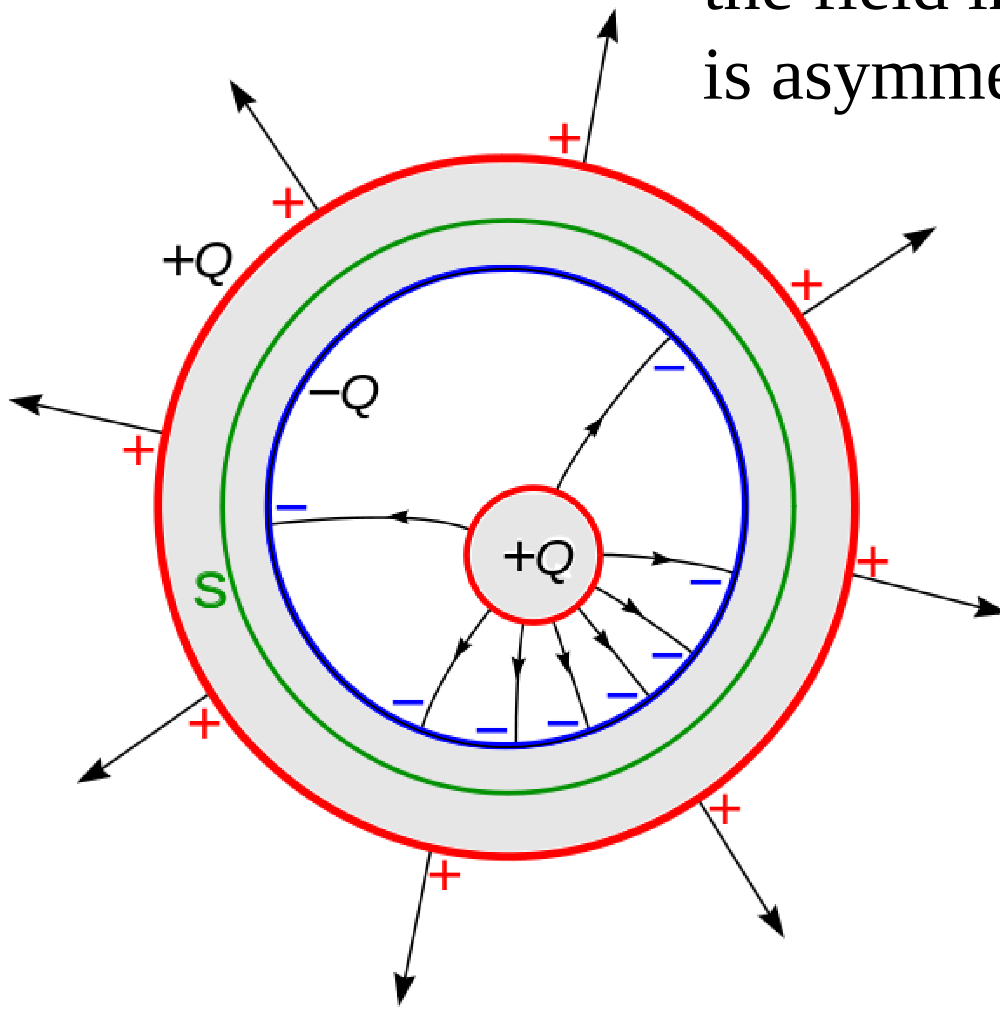
Now suppose the point charge is not in the center of the empty cavity. What changes, if anything?



What will the field look like?

The field E outside the sphere is unchanged, but the field inside the cavity is asymmetric.



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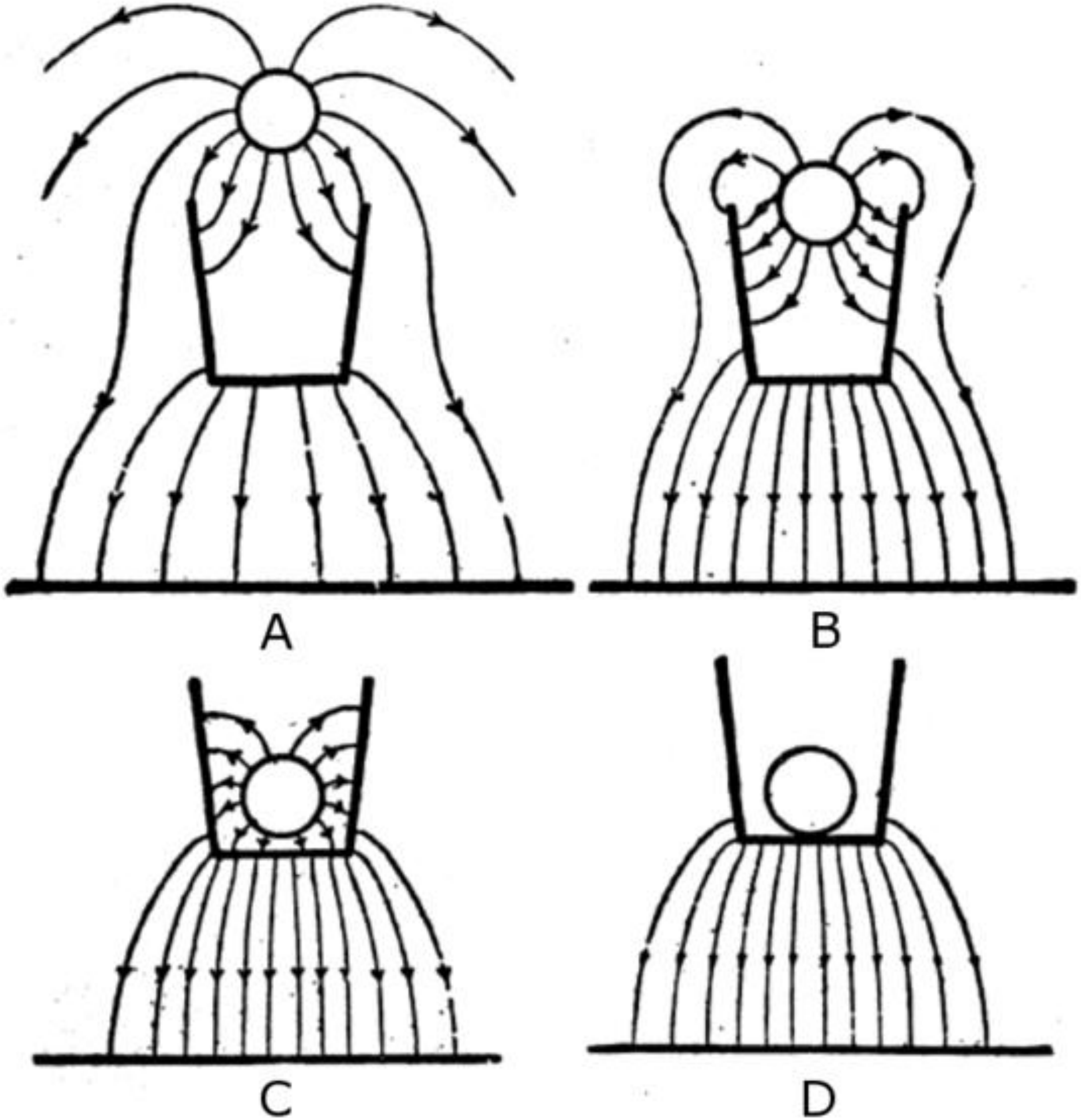

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