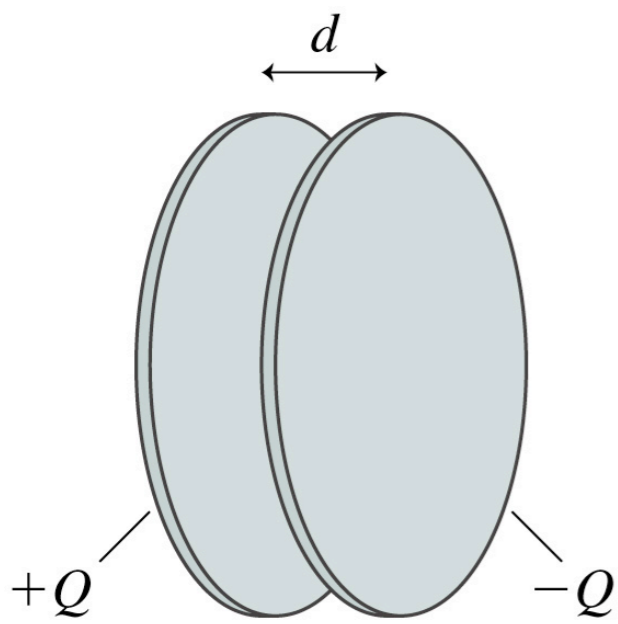


Lecture 19

- This week: parallel-plate capacitor
- motion of charged particle and dipole in \vec{E}
- chapter 28 (Gauss's Law)

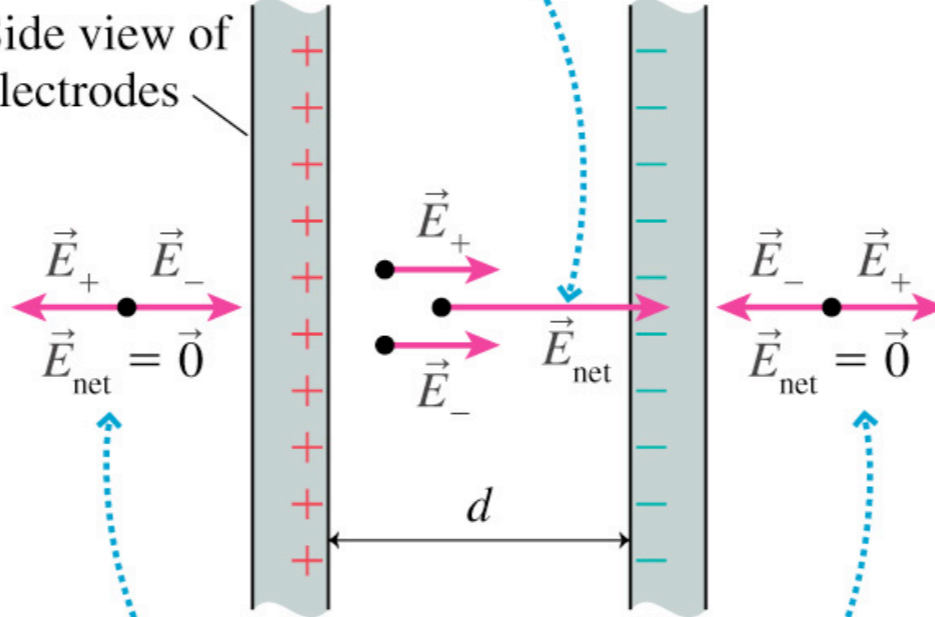
Parallel-Plate Capacitor



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Inside the capacitor, \vec{E}_+ and \vec{E}_- are parallel, so the net field is large.

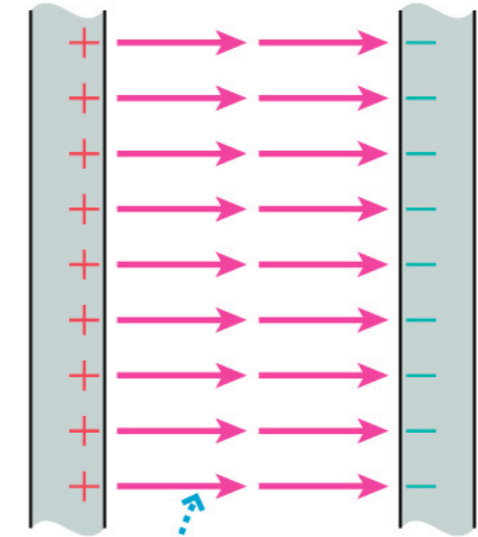
Side view of electrodes



Outside the capacitor, \vec{E}_+ and \vec{E}_- are opposite, so the net field is zero.

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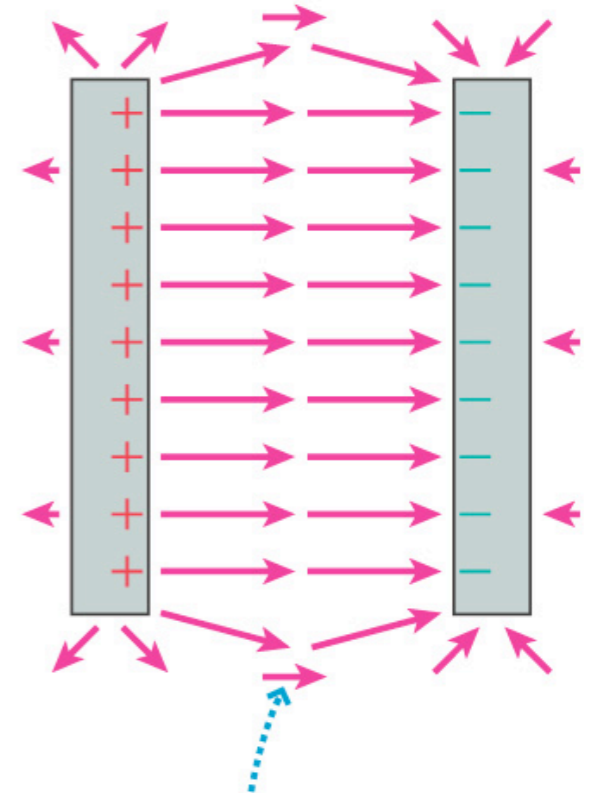
(a) Ideal capacitor



The field is constant, pointing from the positive to the negative electrode.

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(b) Real capacitor



A weak fringe field extends outside the electrodes.

- 2 electrodes with charge $\pm Q$ separated by $d \ll$ size of electrodes

- inside capacitor

$$\vec{E}_{\text{capacitor}} = \vec{E}_+ + \vec{E}_- = \left(\frac{\eta}{\epsilon_0}, \text{ from positive to negative} \right)$$

$$= \left(\frac{Q}{\epsilon_0 A}, \text{ from positive to negative} \right)$$

- $\vec{E} = 0$ outside capacitor

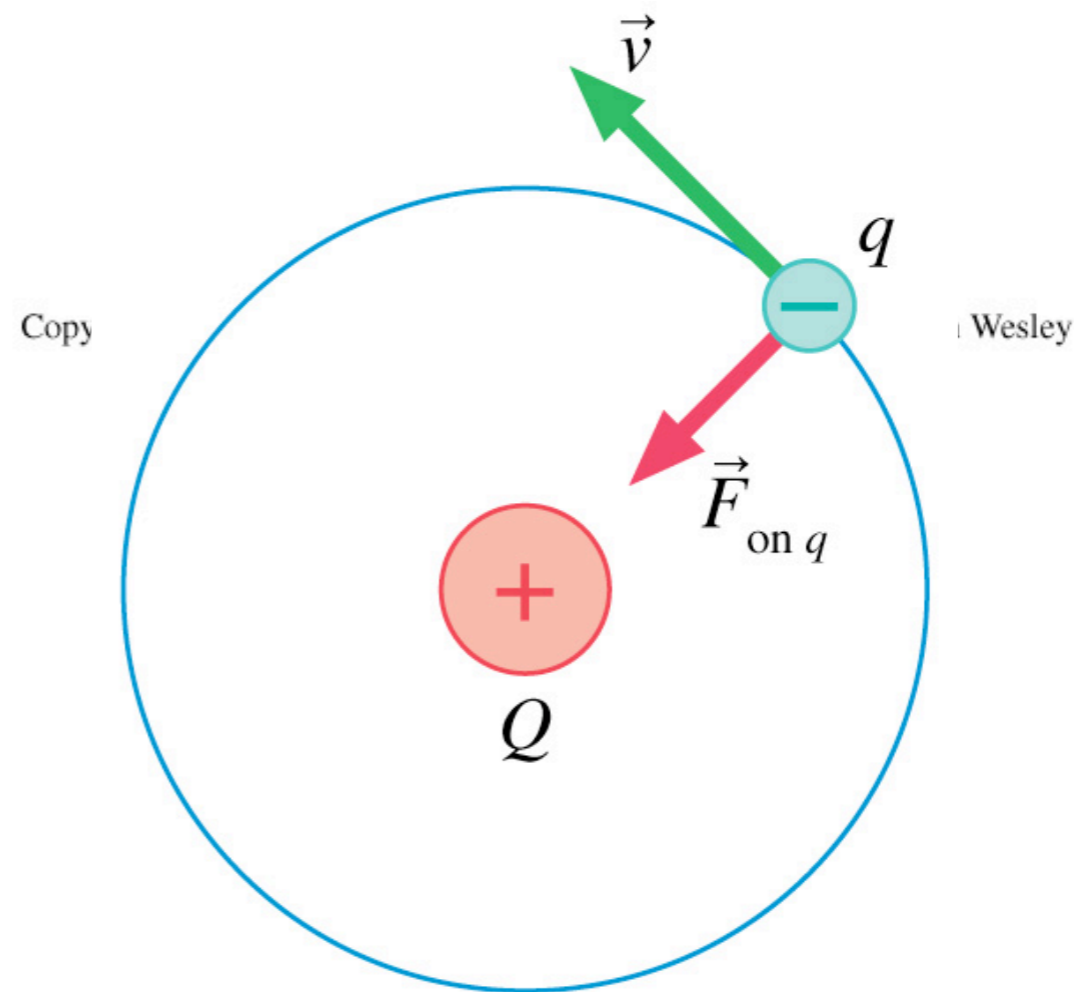
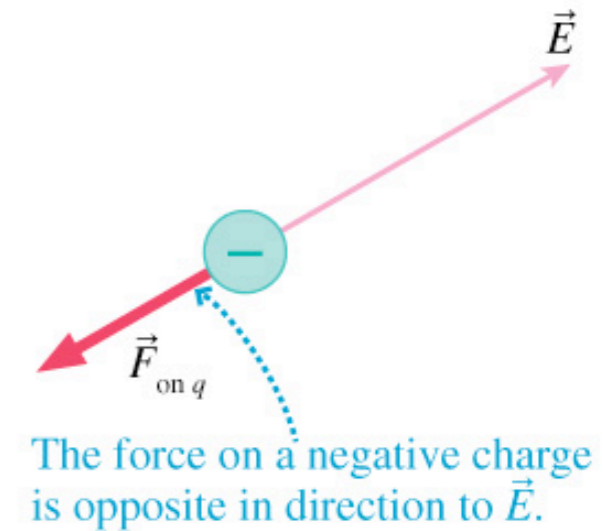
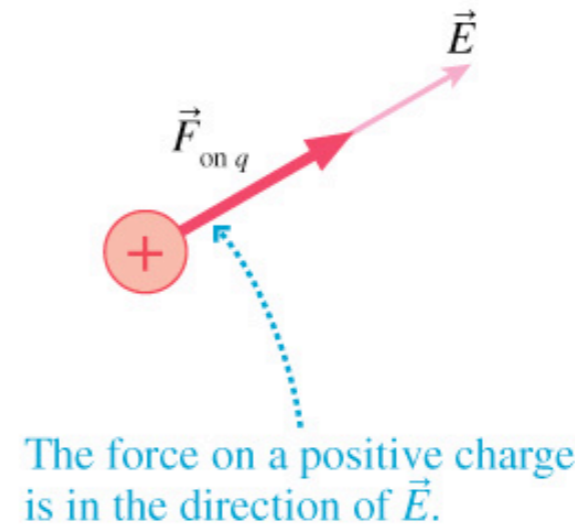
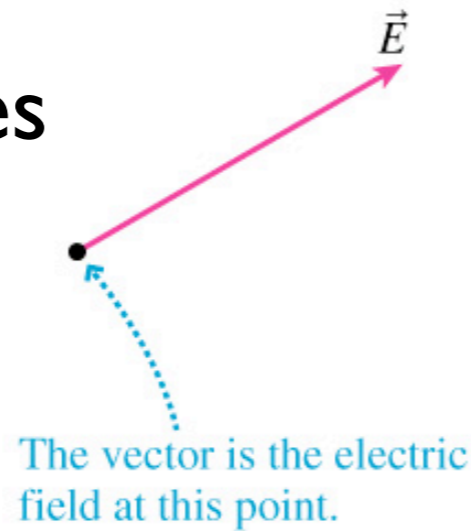
Motion of Charged Particle in Electric Field

- Source charge creates E , other charges respond to it:

$$\vec{F}_{\text{on } q} = q\vec{E} \Rightarrow$$
$$\vec{a} = (q/m)\vec{E}$$

- Uniform E ($a = \text{constant}$): trajectory is parabola (as in gravitational field)
- Non-uniform field e.g. circular motion:

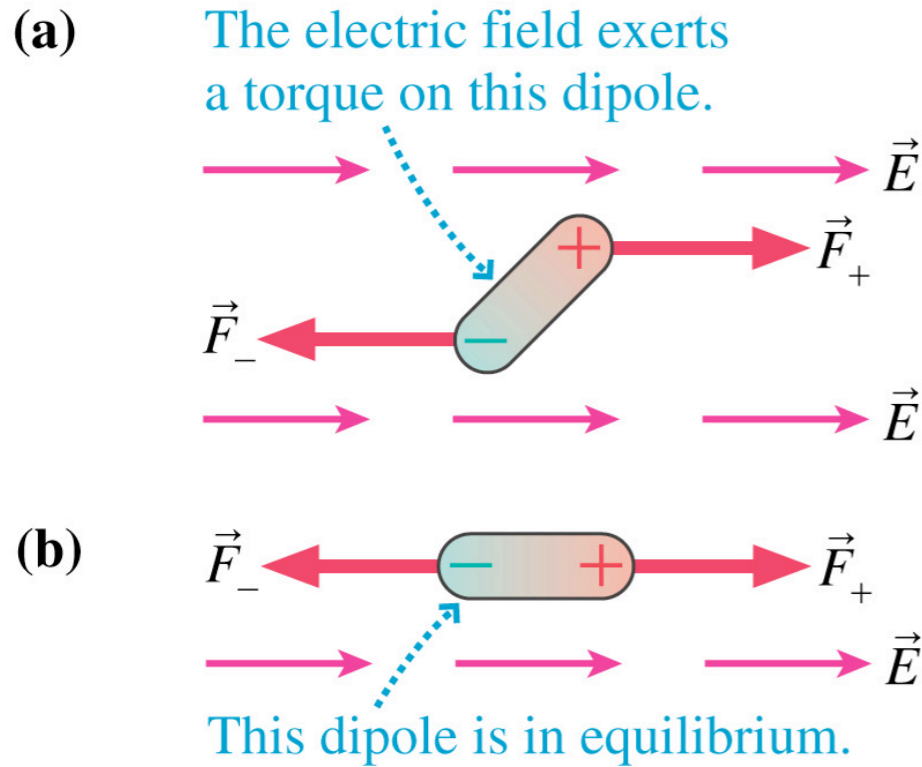
$$|q|E = \frac{mv^2}{r}$$



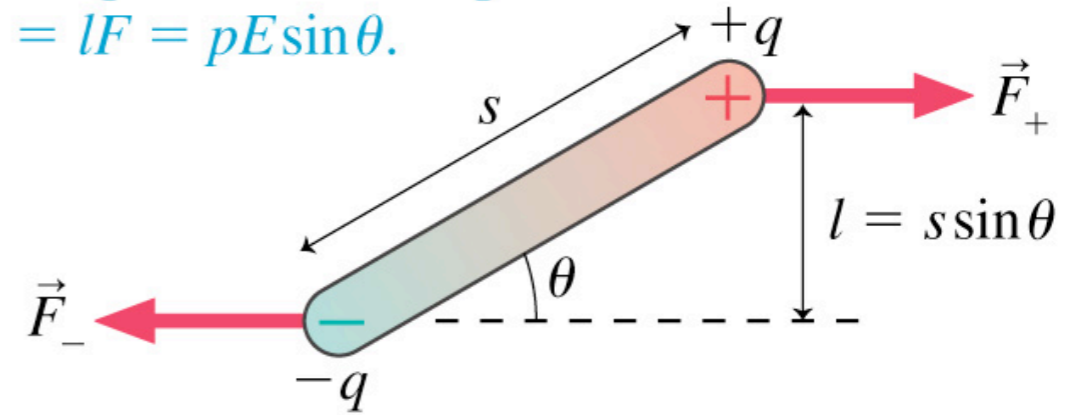
Example

- The surface charge density on an infinite charged plane is $-2.0 \times 10^{-6} \text{ C/m}^2$. A proton is shot straight away from the plane at $2.0 \times 10^6 \text{ m/s}$. How far does the proton travel before reaching its turning point?

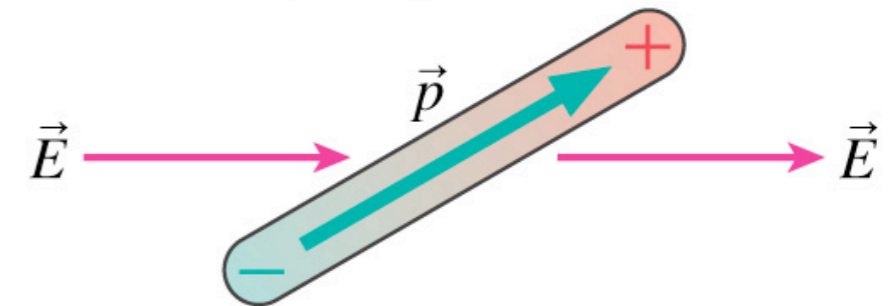
Motion of Dipole in Electric Field



The torque due to a couple is $\tau = lF = pE \sin \theta$.

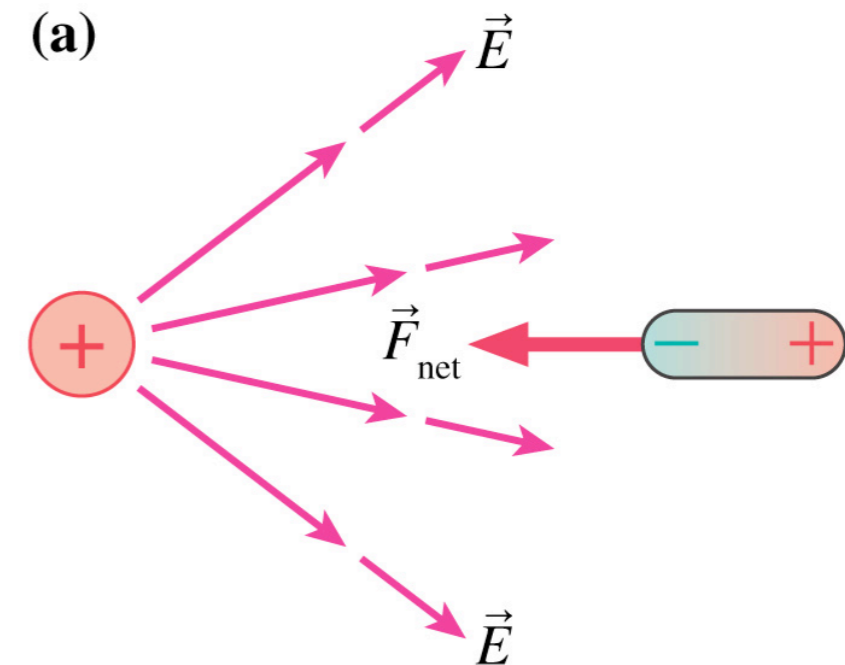


In terms of vectors, $\vec{\tau} = \vec{p} \times \vec{E}$.

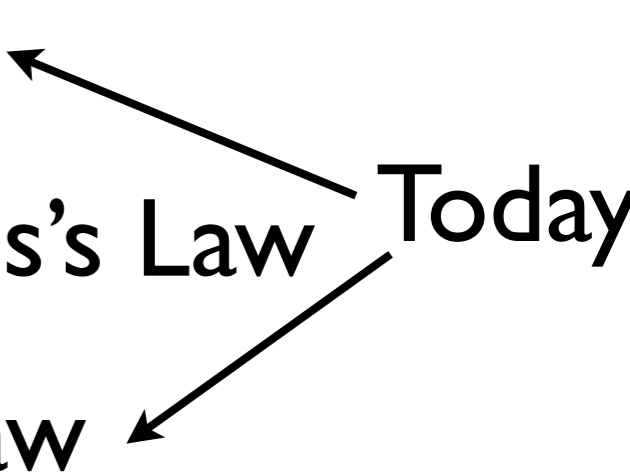


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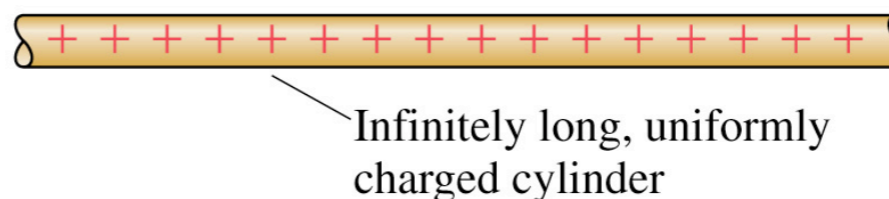
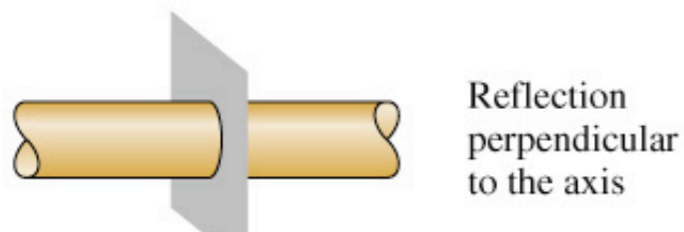
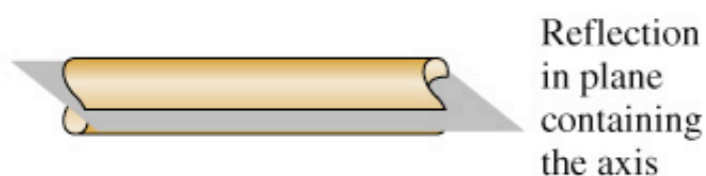
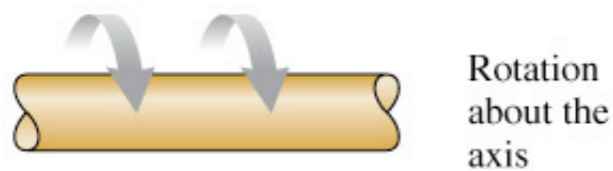
- Polarization force: external charge induced dipole; attractive force on near end > repulsive...charged object attracts neutral...
- Dipole in uniform E: no net force, but torque, causing it to rotate
- Dipole in non-uniform E: first aligns, net force toward stronger field (toward charged object)



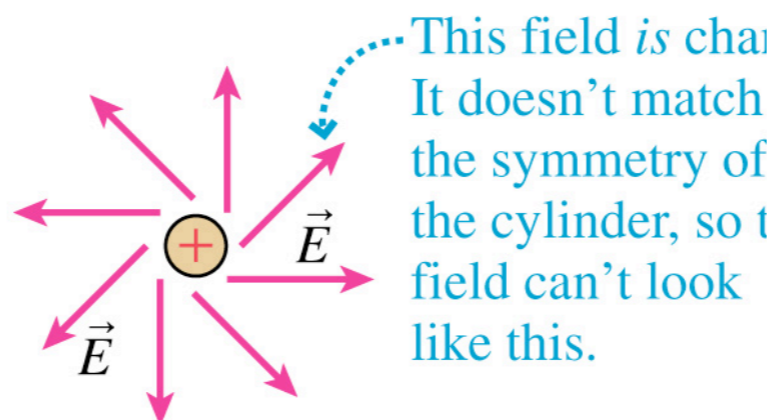
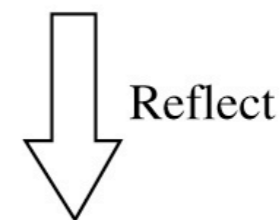
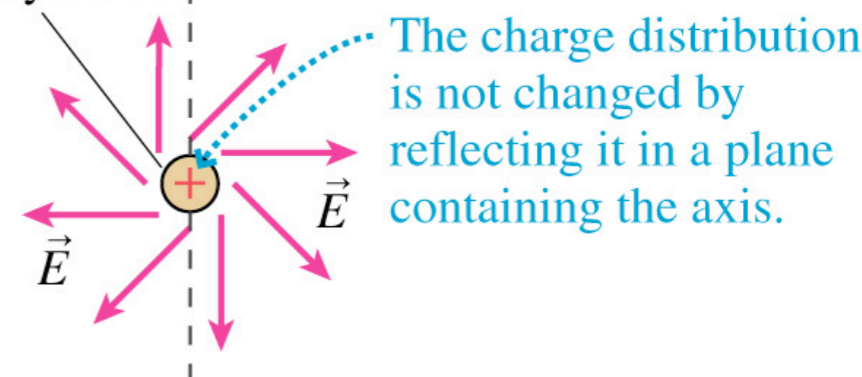
Chapter 28 (Gauss' Law)

- Use symmetry to find geometry of \vec{E}
 - For such fields, calculate \vec{E} using Gauss's Law
 - Concept of Electric Flux in Gauss's Law
 - Use Gauss's Law to understand conductors
- Today
- 

Symmetry (unchanged under geom. transformation)



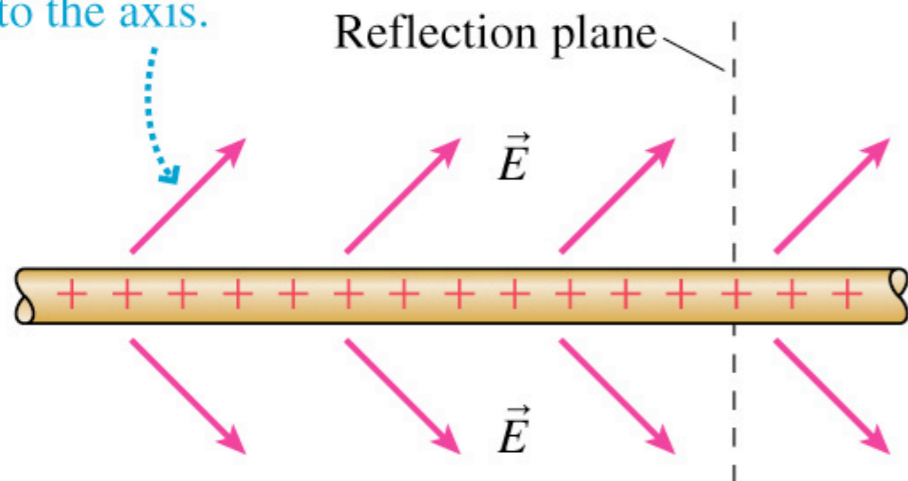
(a)



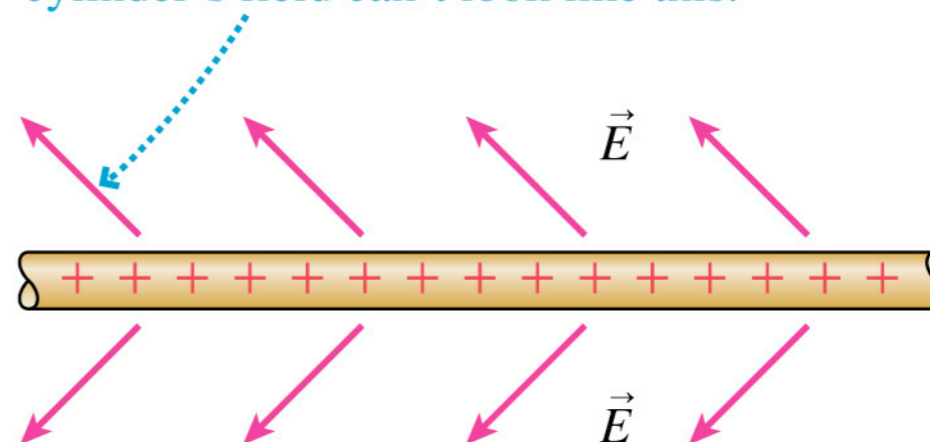
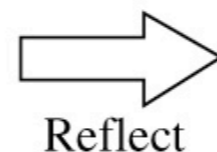
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(a) Is this a possible electric field of an infinitely long charged cylinder? Suppose the charge and the field are reflected in a plane perpendicular to the axis.

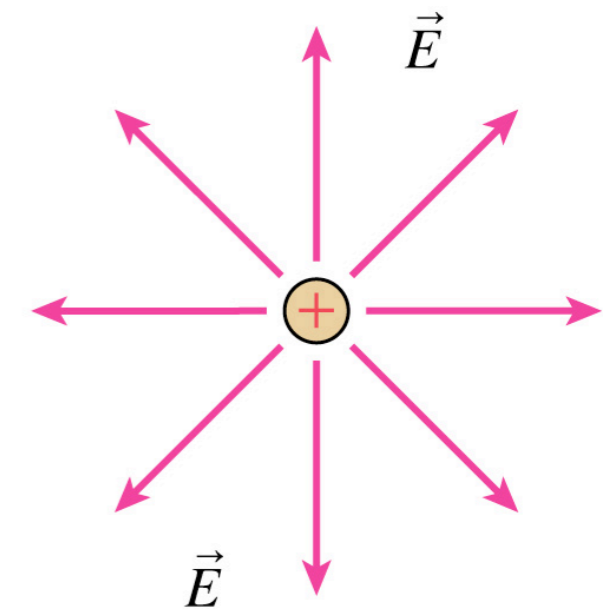
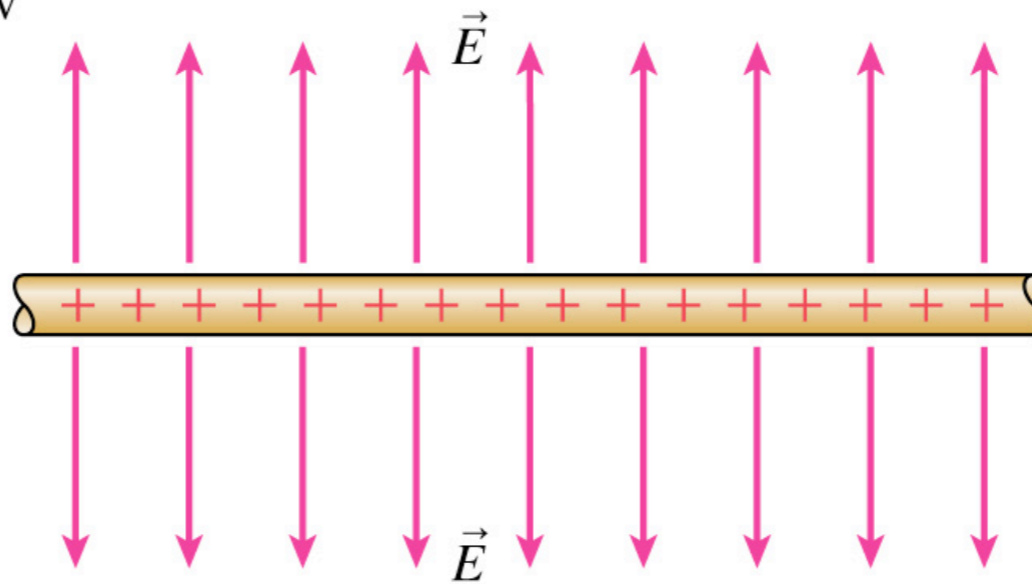


(b) The charge distribution is not changed by the reflection, but the field is. This field doesn't match the symmetry of the cylinder, so the cylinder's field can't look like this.



Symmetry II

- must be...
- 3 fundamental symmetries

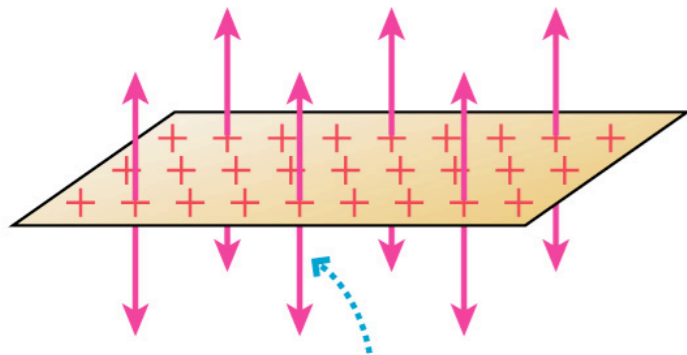


Cylindrical symmetry

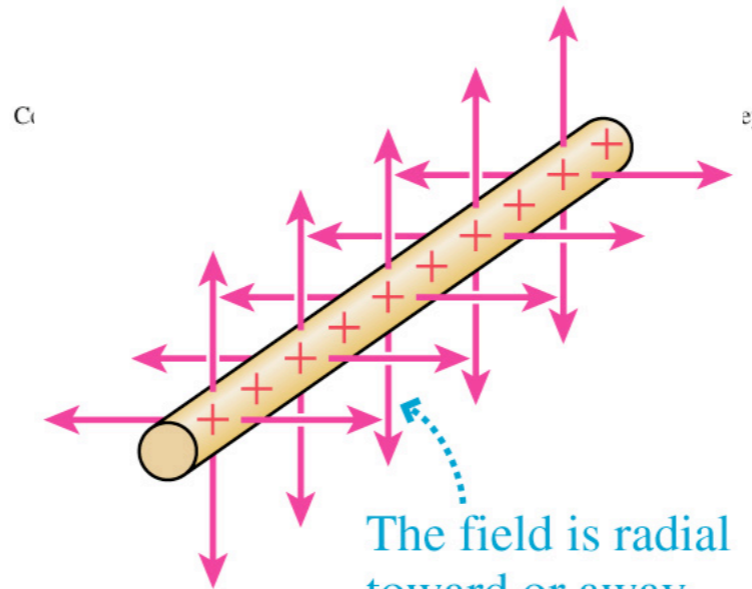
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Spherical symmetry

Planar symmetry

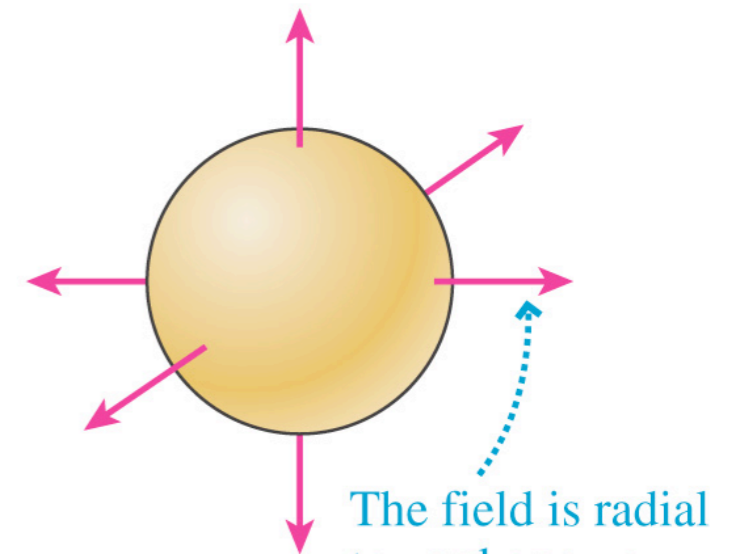


The field is perpendicular to the plane.



The field is radial toward or away from the axis.

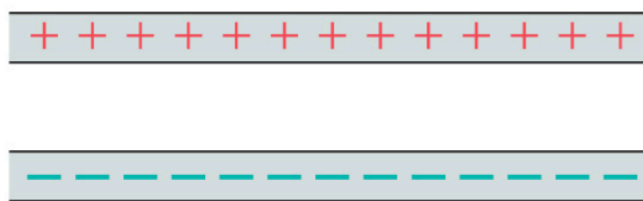
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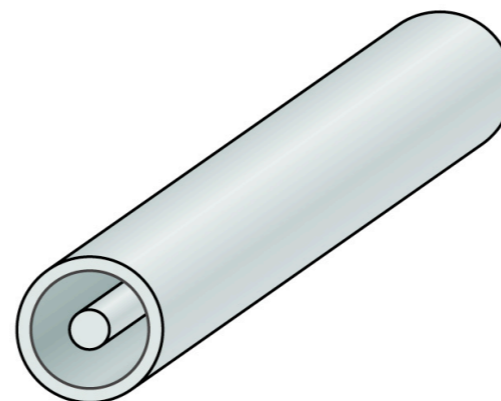
The field is radial toward or away from the center.

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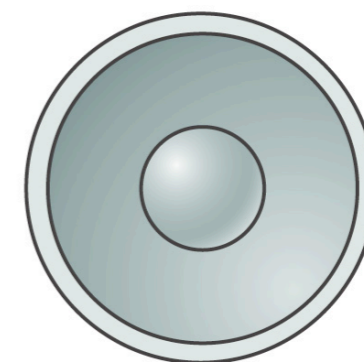
More complex example:



Infinite parallel-plate capacitor



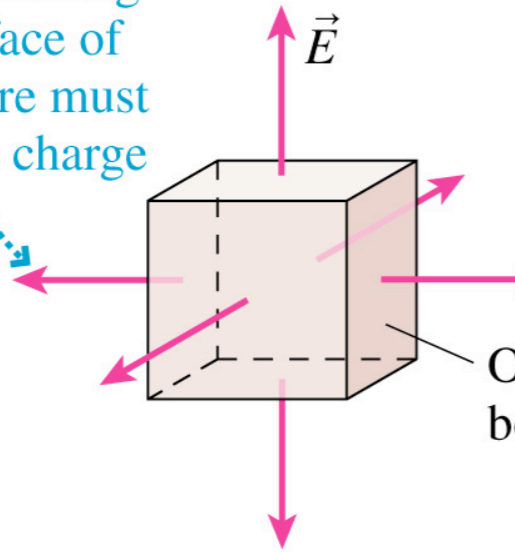
Coaxial cylinders



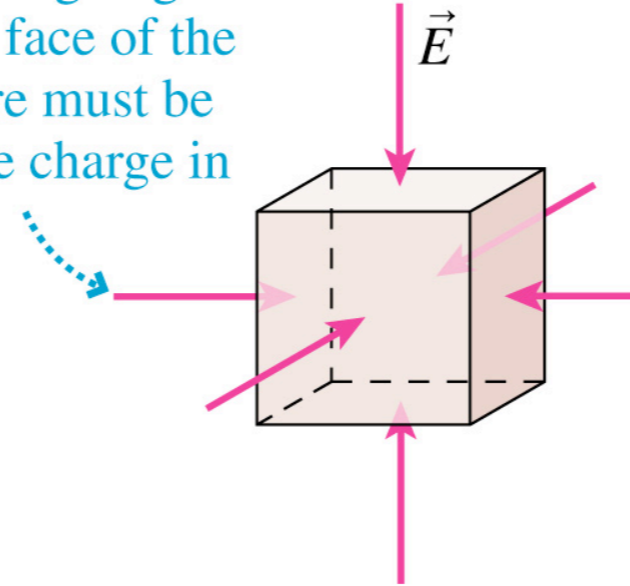
Concentric spheres

Concept of Flux I

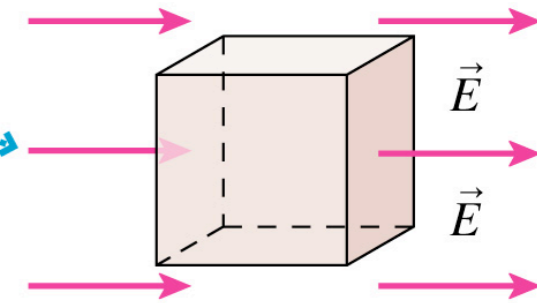
(a) The field is coming out of each face of the box. There must be a positive charge in the box.



(b) The field is going into each face of the box. There must be a negative charge in the box.



(c) A field passing through the box implies there's no net charge in the box.



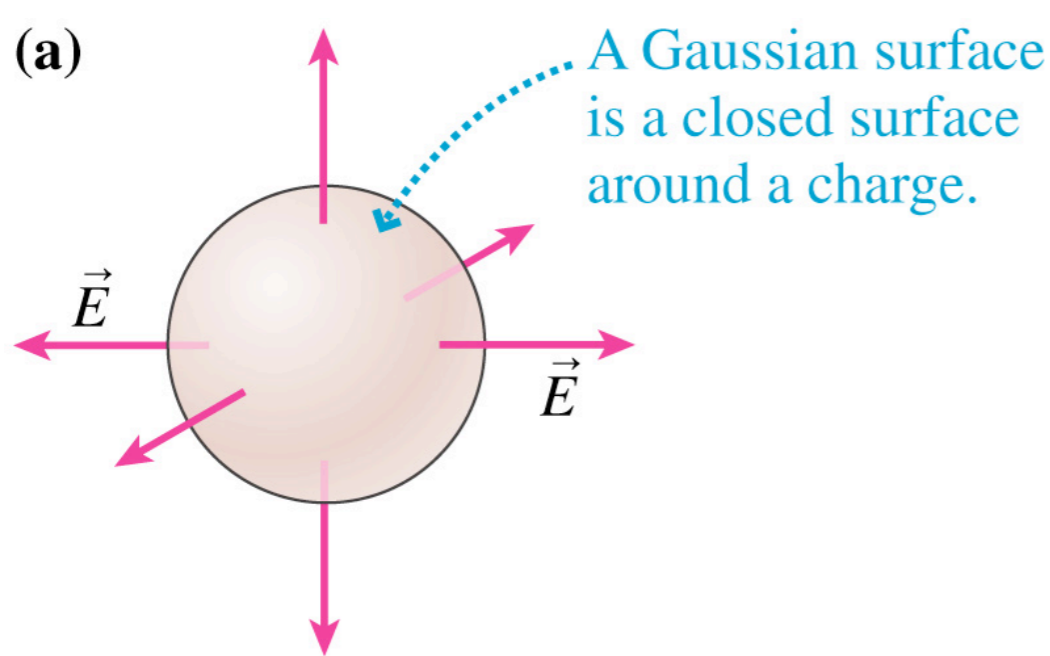
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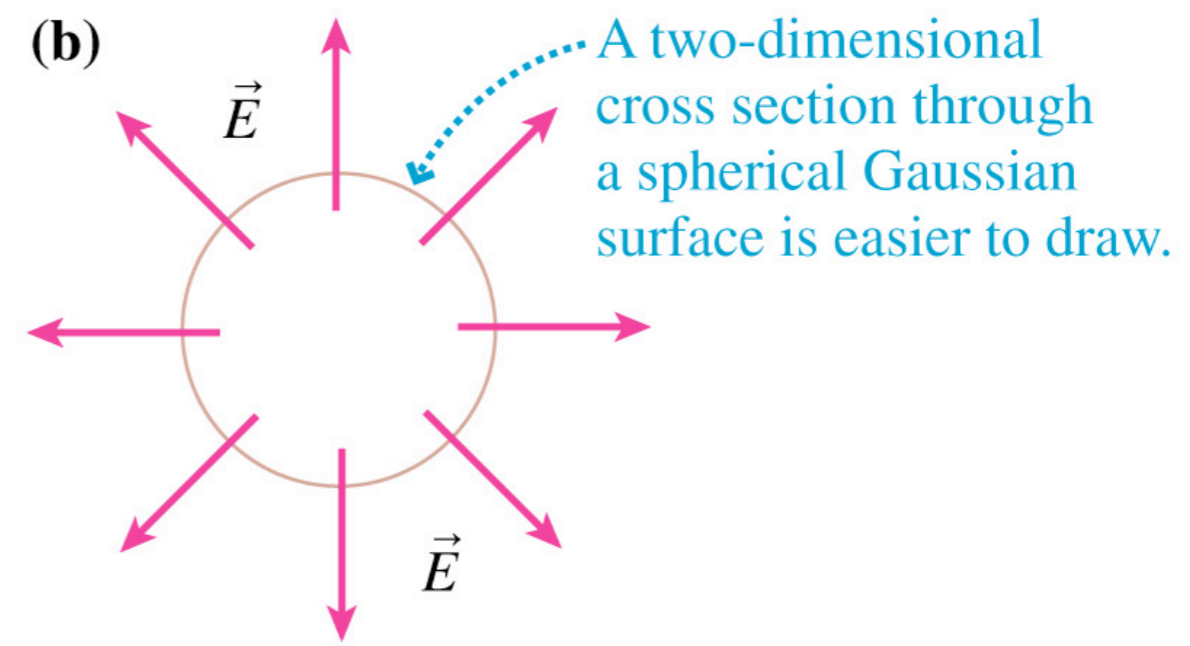
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- outward flux (“flow”) of \vec{E} thru’ closed (Gaussian) surface for next positive charge inside
- inward...for...negative...
- no net flux...net charge

Concept of Flux II

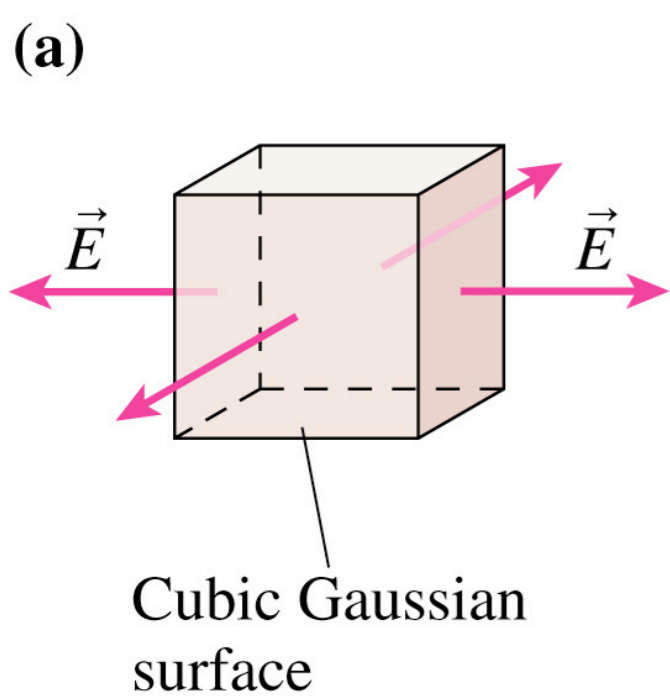


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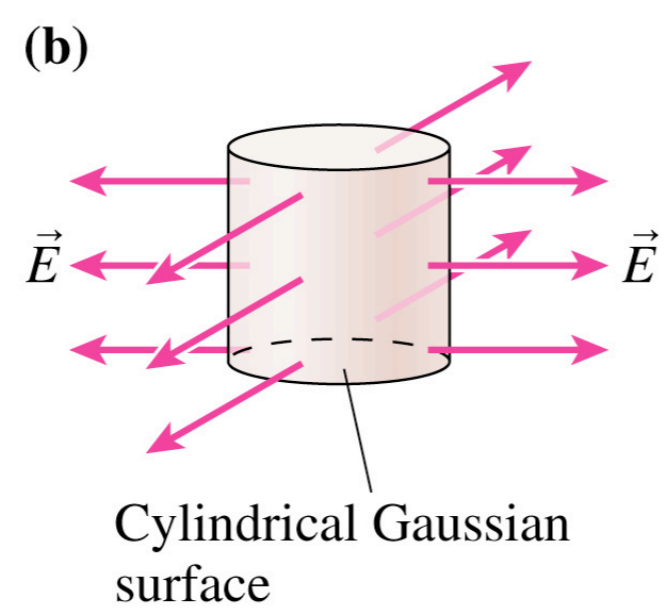


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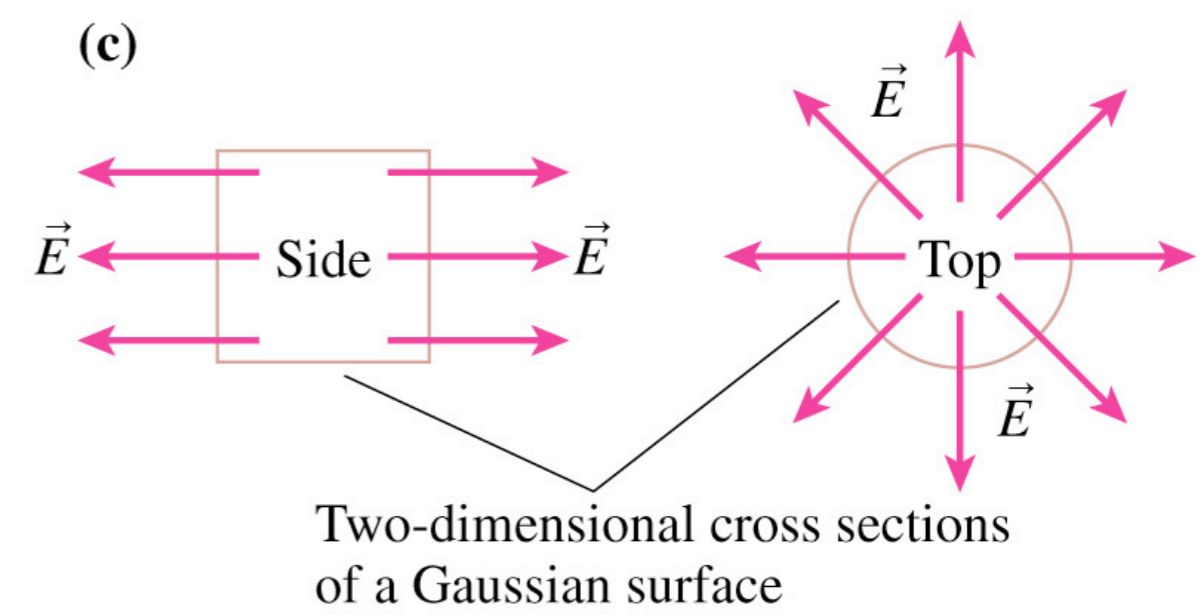
- match closed surface to symmetry of \vec{E} / charge distribution



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