Physics 122 – Class #14 – Outline

- Announcements
- Electric Field
  - Superpositions
  - Gaining intuition from electric field lines
  - Effect of electric field on moving charges
- Empirical Electrostatics
- Field of continuous distributions

Test #2 … before or after break?

We will have a brief discussion with arguments for both sides and we will take a clicker vote.

… on Tuesday 3/3/15.
Feel free to build your coalition.

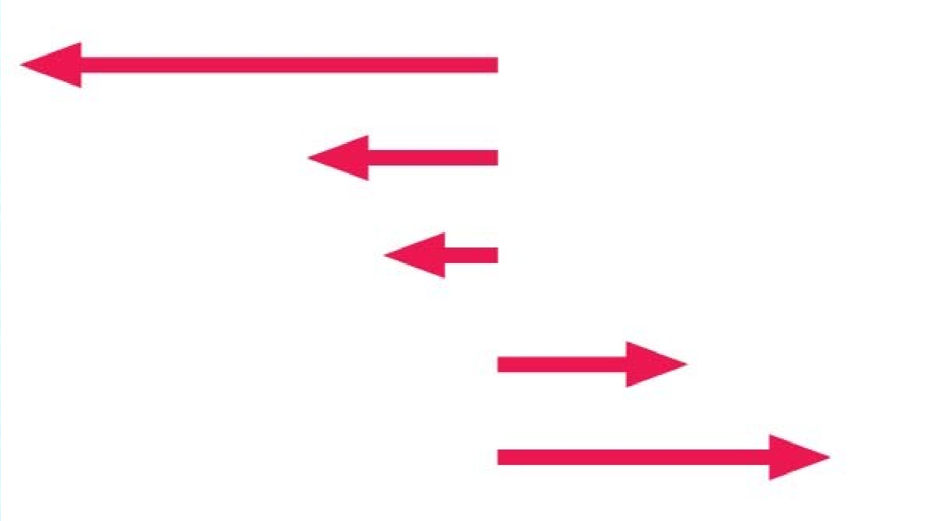
Material will be slightly different depending on test timing …

I will have graded test #1 by then.

Clicker – Review of Coulomb's Law

The charge of sphere 2 is twice that of sphere 1. Which vector below shows the force of 2 on 1?

A.
B.
C.
D.
E.



$$\vec{F}_{12} = k \frac{q_1 q_2}{r_{12}^2} \hat{r}_{12}$$

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Steps to solve a superposition problem

1) Identify the charge (or point P) at which you want to calculate the force (or field).

2) Draw an arrow (a vector) representing the Force Vector (or Field Vector) at the charge along a line joining it with each of the other charges.

3) Make the length of the vectors proportional to the force between the charges (shorter arrows for more distant charges)

4) Add the vectors using the tip to tail method to find the *resultant*.

Electric Field

The force/Coulomb felt by an infinitesimal charge from all other charges in the area (not including itself).

$$\overrightarrow{F_{12}} = k\frac{q_1 q_2}{r_{12}^2}\widehat{r_{12}}$$

$$\overrightarrow{E_{12}} = k\frac{q_2}{r_{12}^2}\widehat{r_{12}}$$

$$\overrightarrow{F_{12}} = q_1\overrightarrow{E_{12}}$$

Don't forget that “the hat” means a vector of magnitude 1.

Electric Field Magnitudes

Given

$q = 10\ \text{nC},\ r = 3\ \text{m}$

$$\vec{E}_2 = k\frac{q_1}{r_{12}^2}\widehat{r_{12}}$$

$$k = 9\times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}$$

$E = ?$

[A] $1\ \text{N/C}$

[B] $3\ \text{V/m}$

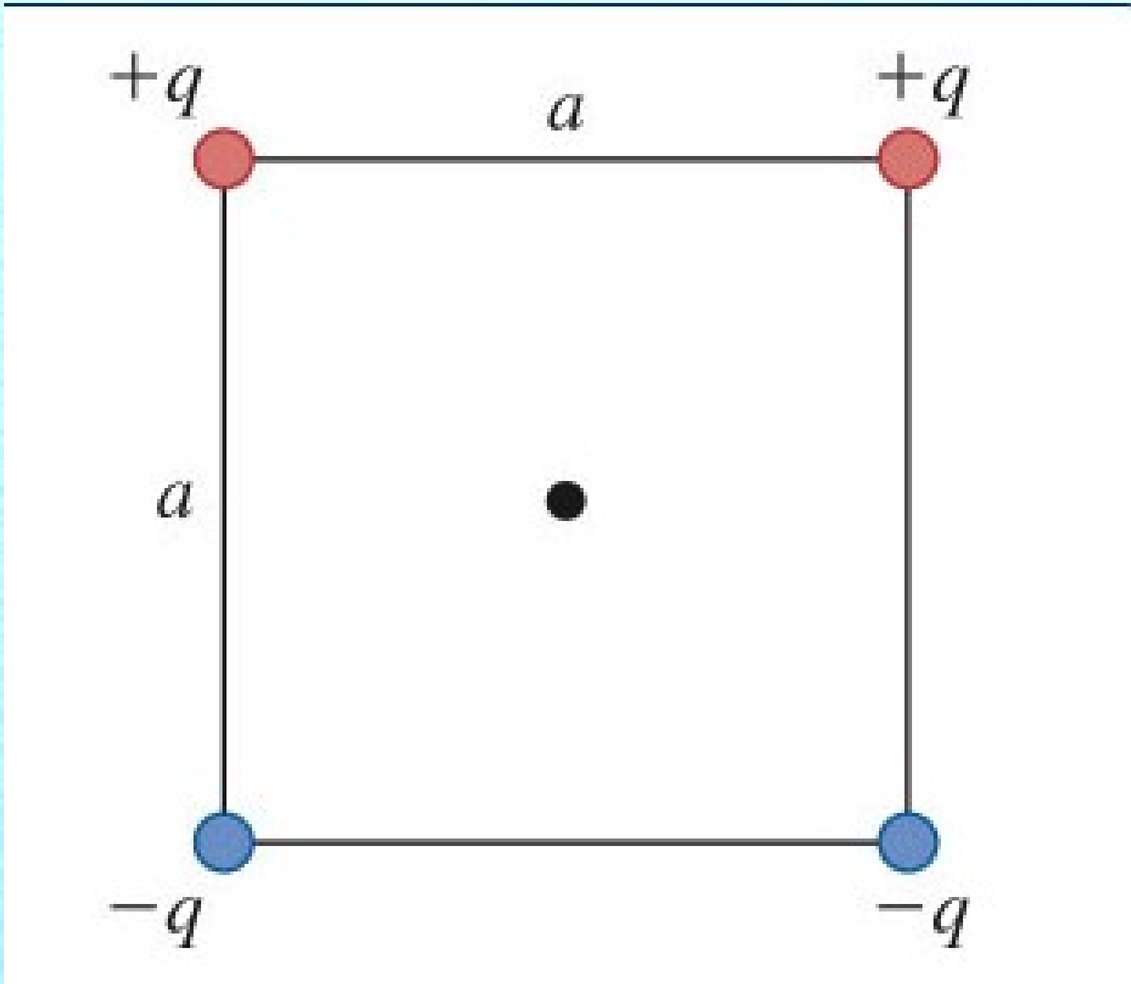
[C] $10\ \text{N/C}$

[D] $30\ \text{N/C}$

[E] $90\ \text{N/C}$

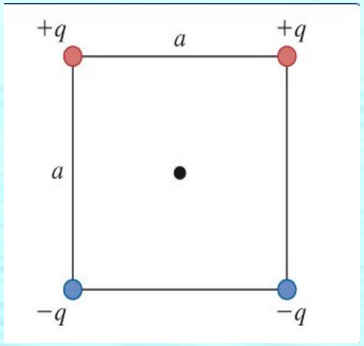
Problem 25.37

Electric Field Superposition



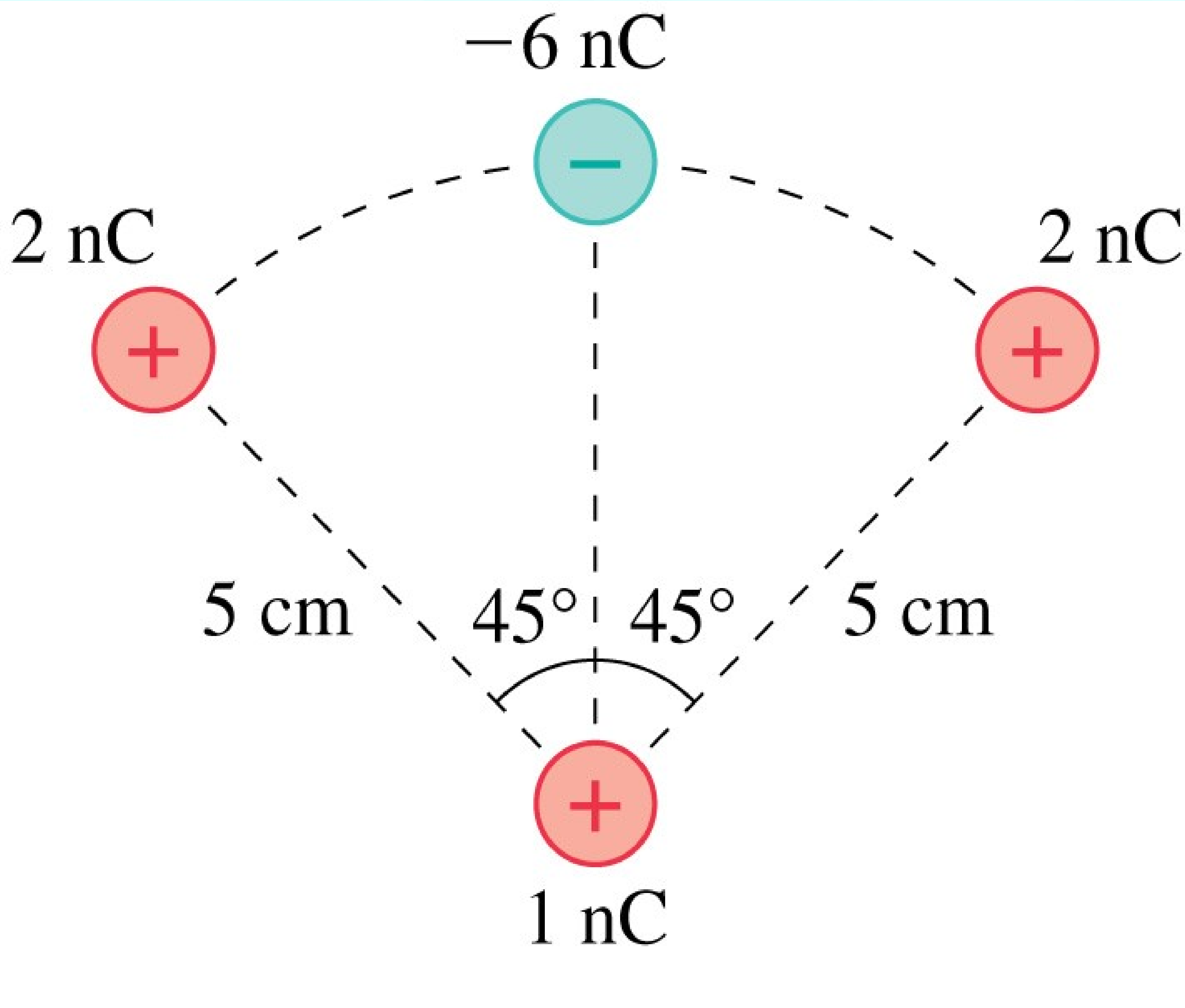
Given four identical charges at corners of a square, find direction of field in the center of the square, and in the middle of each side.

Electric Field Superposition



Given four identical charges at corners of a square, find direction of field in the center of the square, and in the middle of each side.

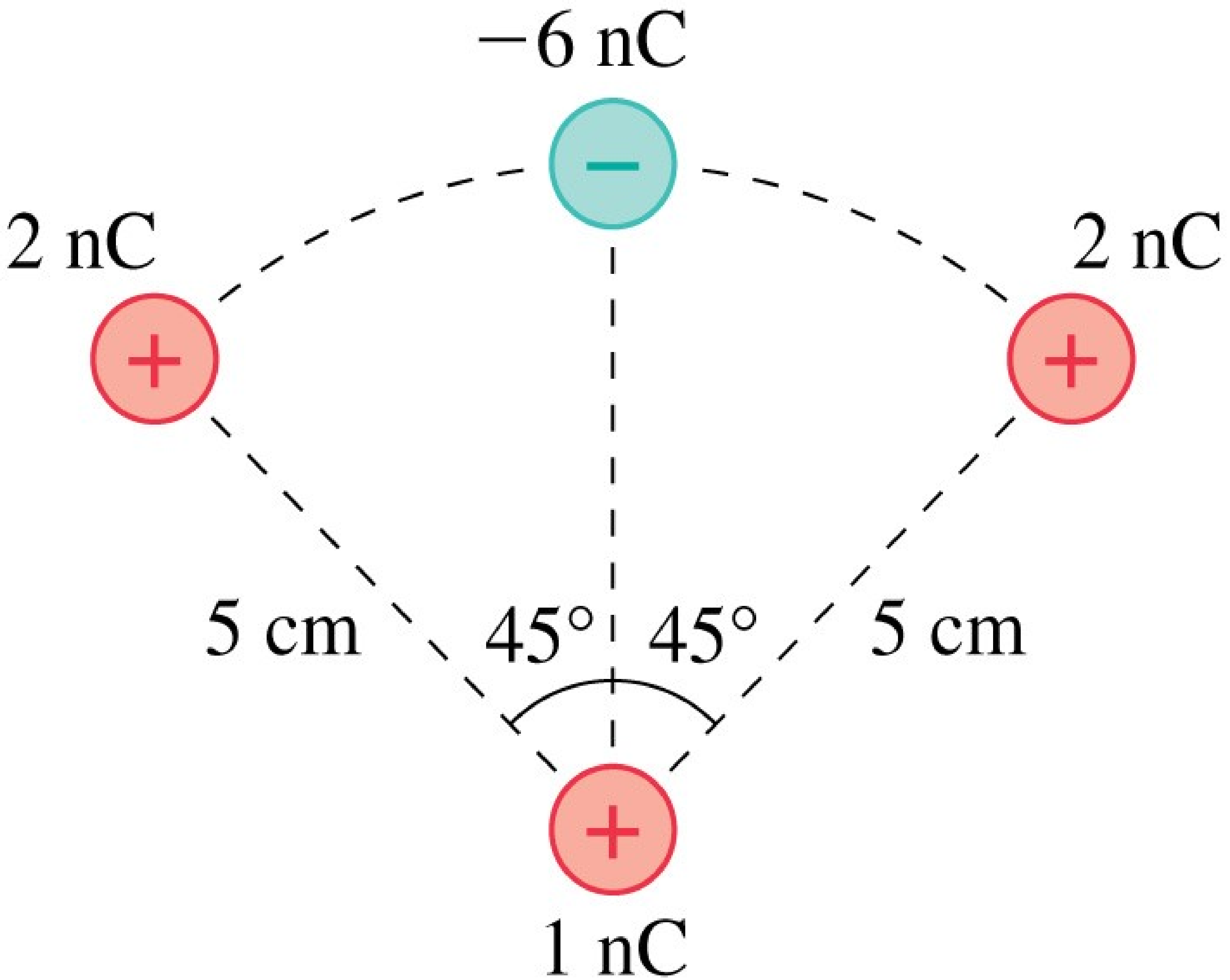
Superposition problem #3



What is the direction of the field at the
1 nC charge?

Is it
(A) Up
(B) Down
(C) Zero
(D) Left
(E) Right

Superposition problem #3



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Using electric field to find force

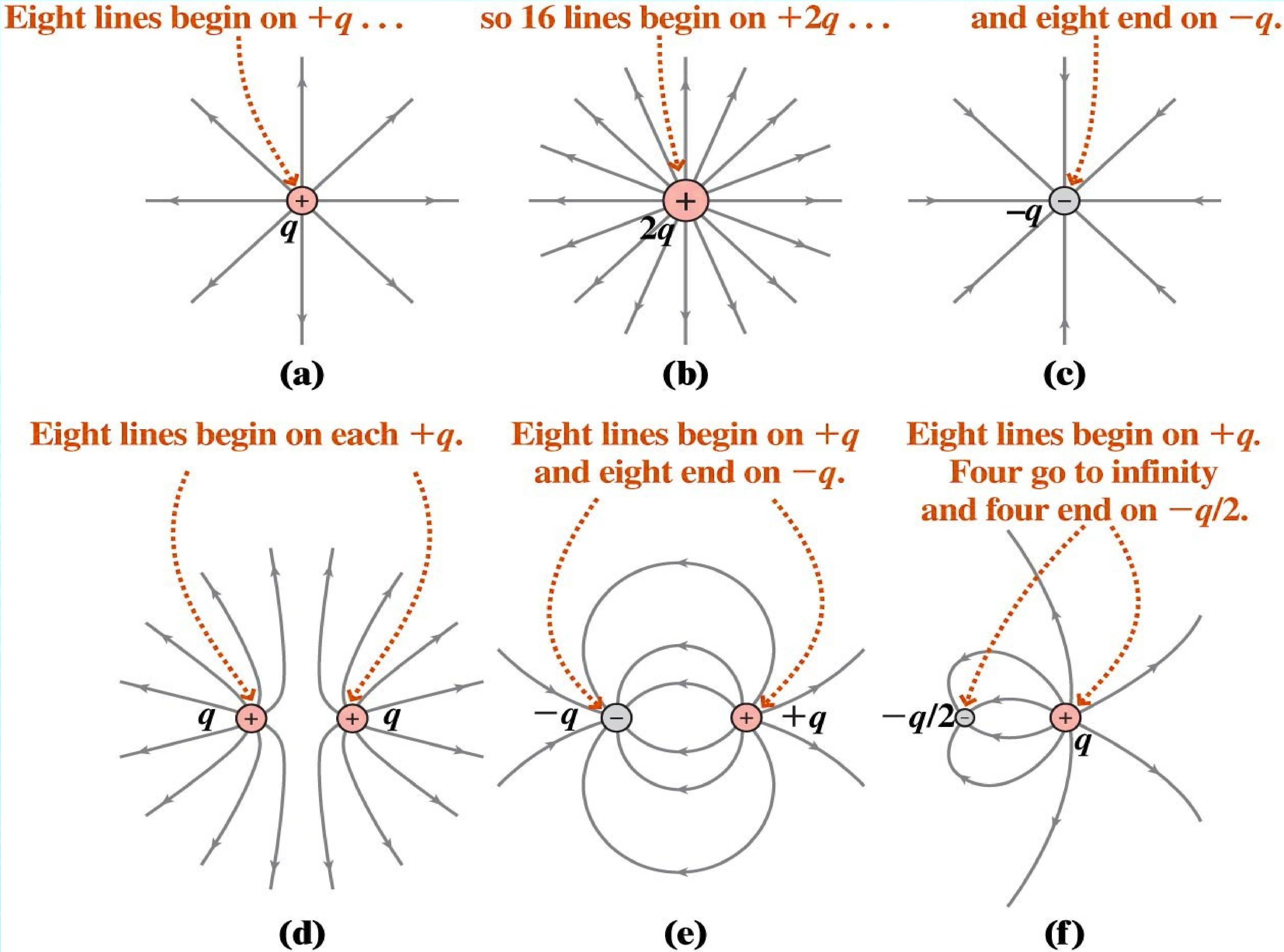
Although electric field is DEFINED as Force felt by an infinitesimal positive charge, if you KNOW the field (and it can be measured) then you can find the force on ANY charge with: $\vec{F} = q\vec{E}$

Note that force on negative charge is opposite positive charge.

Electric Field Lines

- A way of getting intuition for the fields caused by a few charges (without calculating)

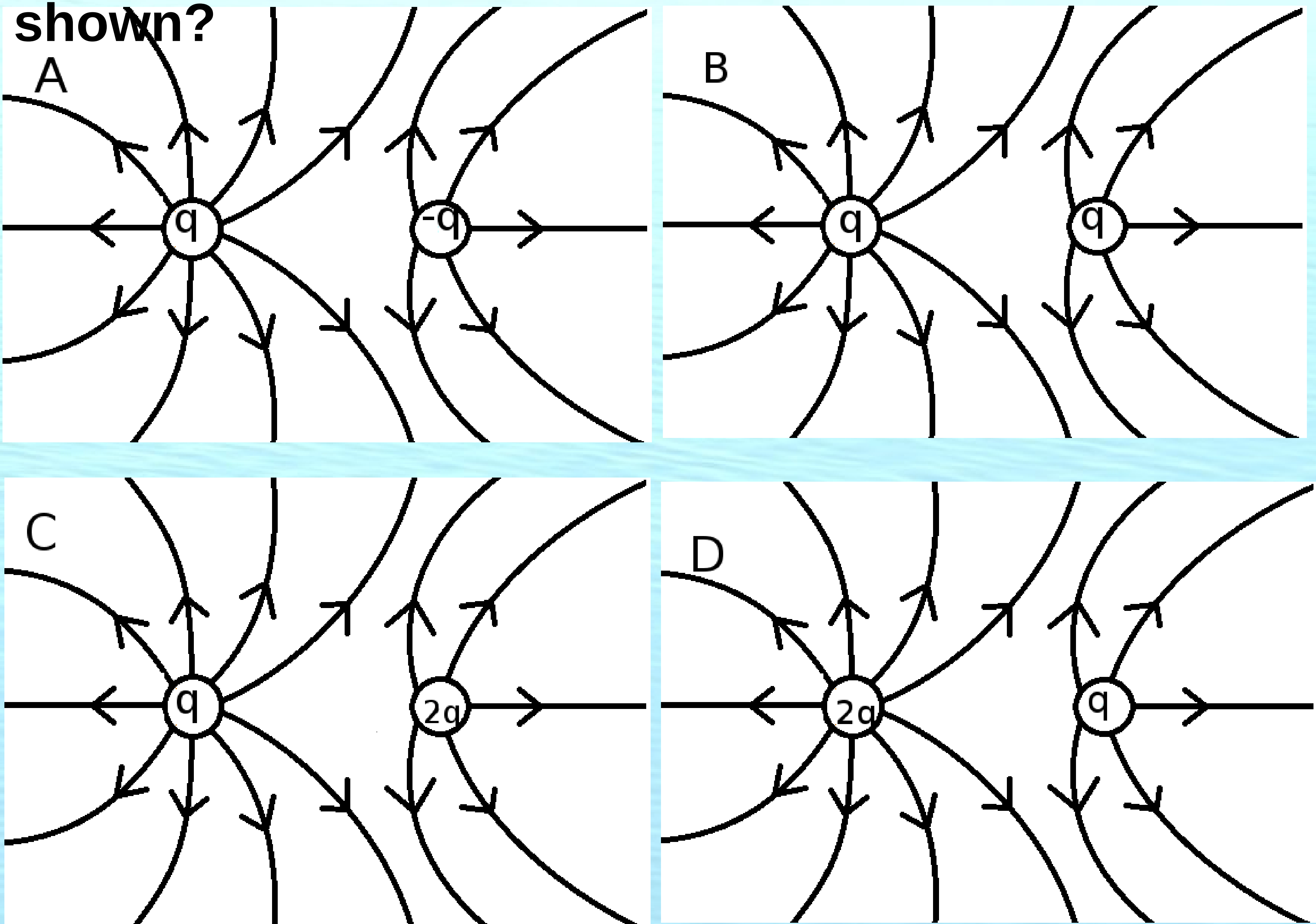
- Positive charges "emit" field lines.
- Negative charges "absorb" field lines.
- Field lines begin at + charge and end at infinity or negative charge.
- The tangent to an electric field line gives direction of force
- Electric field lines do not cross



Eight lines begin on +q . . .
so 16 lines begin on +2q . . .
and eight end on −q.
+
q
+
2q
−
−q
(a)
(b)
(c)
Eight lines begin on each +q.
Eight lines begin on +q
and eight end on −q.
Eight lines begin on +q.
Four go to infinity
and four end on −q/2.
q
+
+
q
−q
−
+
+q
−q/2
−
+
q
(d)
(e)
(f)

PheT …
Charges and fields
Electric field of dreams

Which set of field lines corresponds to charges shown?



Clickers: Can electric field lines ever cross each other?

(a) Yes!!

(b) No!!

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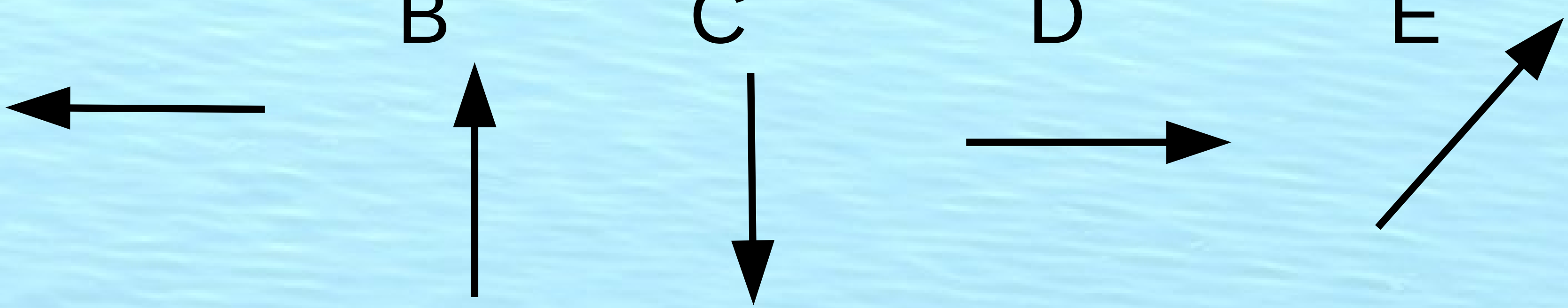
Clicker

The green arrows represent velocity vectors vs. time for a positively charged particle. Which arrow below represents the Electric field direction causing this?

A B C D E



Clicker

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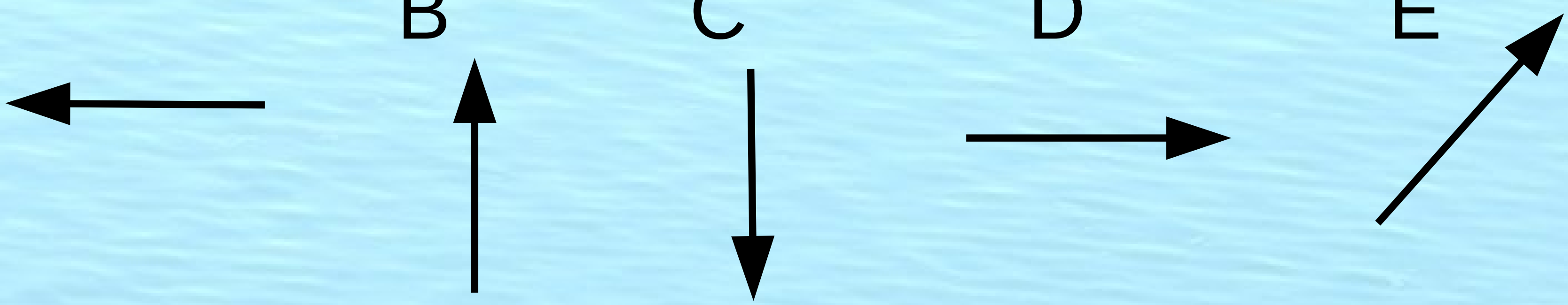


Problems

Electric field needed to accelerate a proton to 1000 km/s from rest in 2 meters?

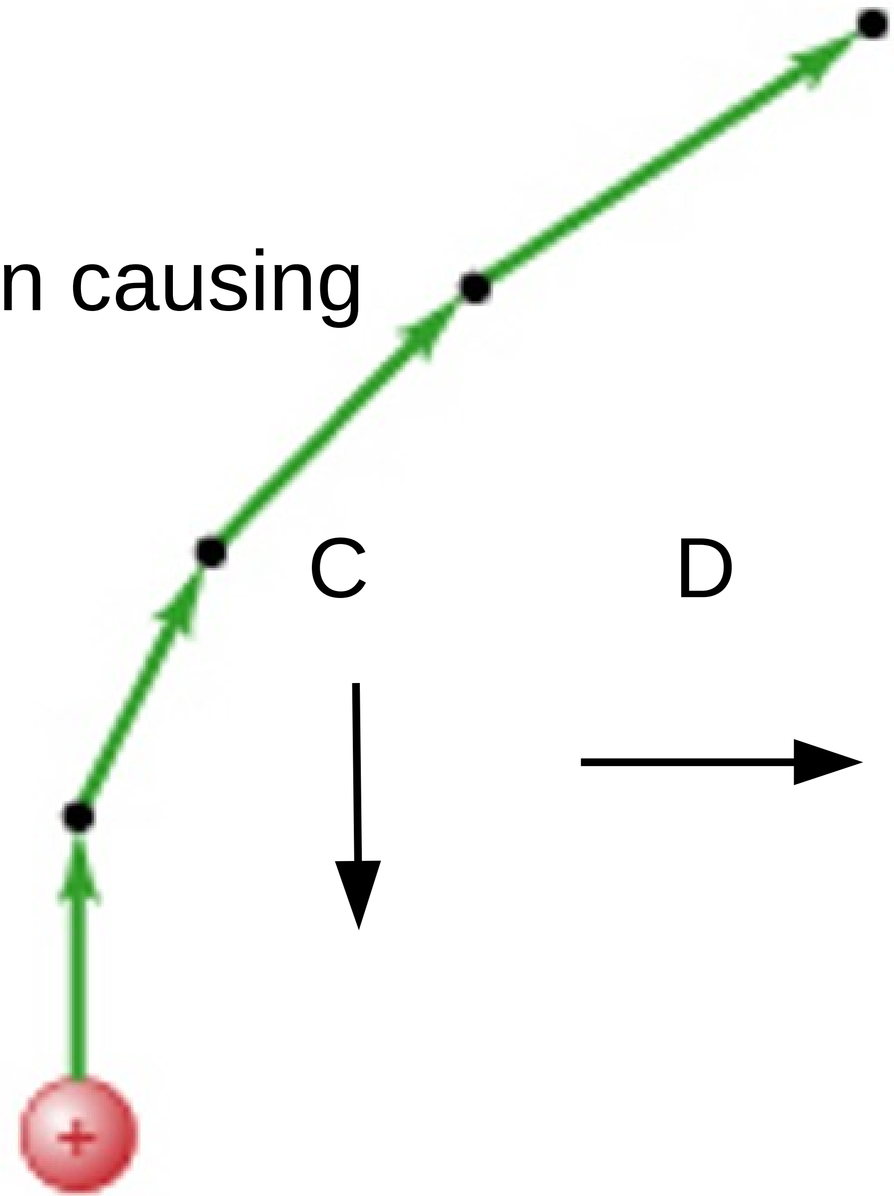
$$q_p = 1.6 \times 10^{-19}\,C \qquad m_p = 1.67 \times 10^{-27}\,kg$$

$$W = \vec{F} \cdot \Delta \vec{r} = K_f - K_i$$

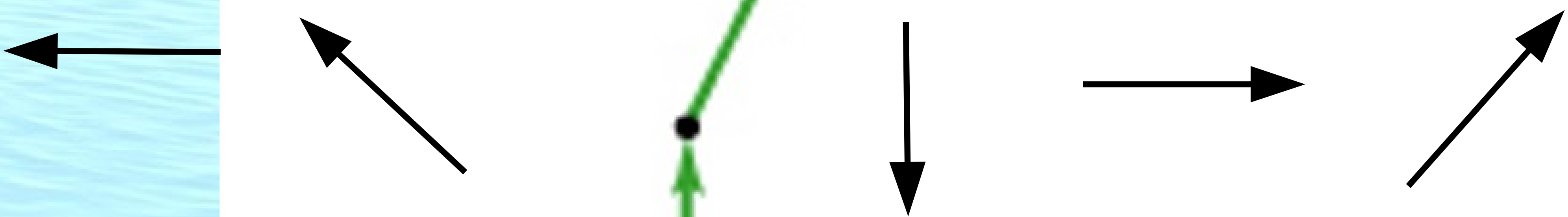
$$v_f^2 - v_i^2 = 2a\Delta x$$

Clicker

Which arrow below represents the Electric-field direction causing this?



A B C D E



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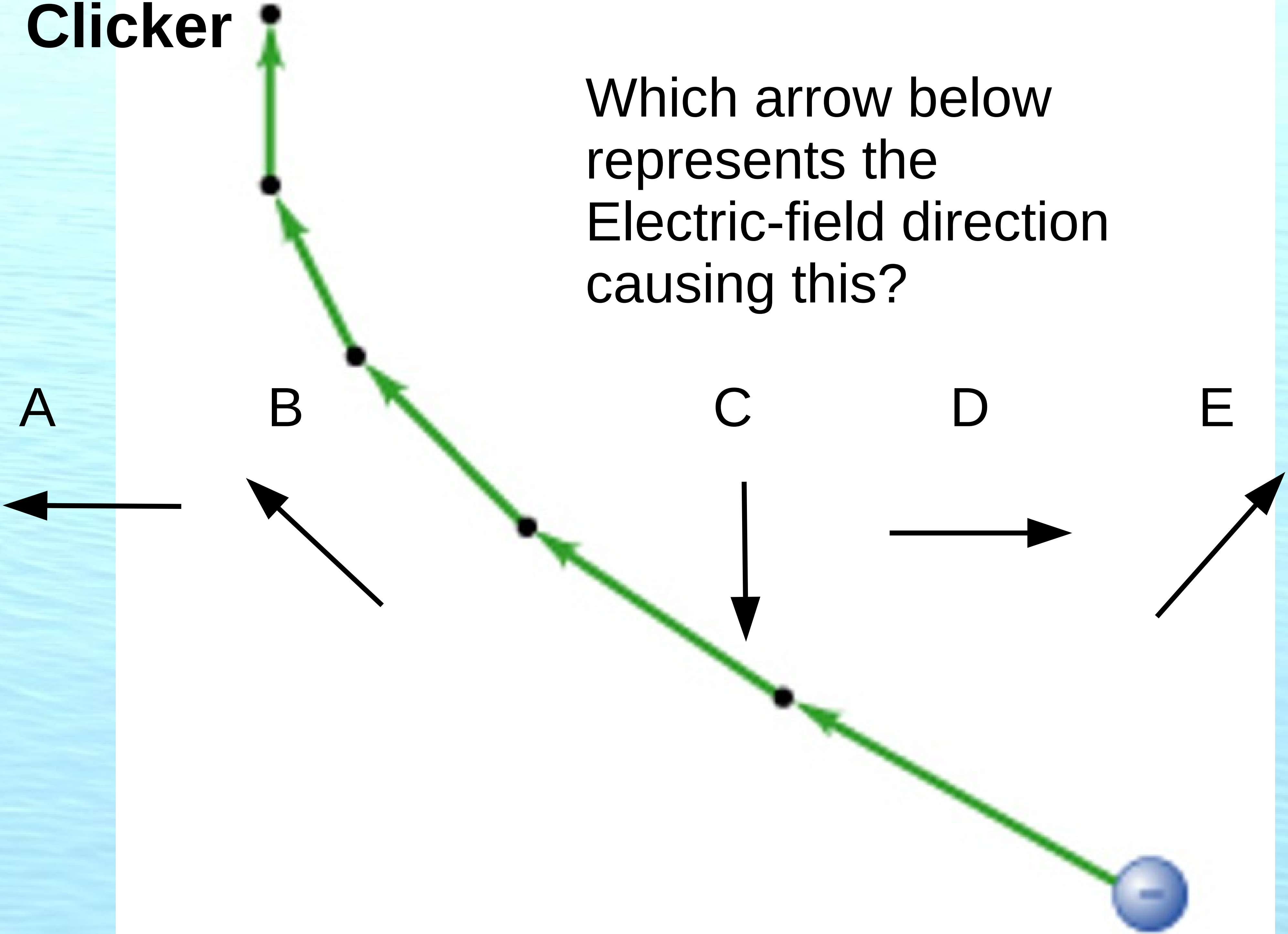

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Ben Franklin's Electricity

You can transfer charge to an insulator by rubbing it. (Rubbing glass with cotton makes it “positive”)

You can rub a charged insulator on a Conductor to transfer charge to it.

You can charge a conductor by “induction”

You can create a force on a neutral object by polarization.

Triboseries

THESE CHARGE POSITIVE

acrylic (lucite, plexiglas)

glass

wool

silk

nylon

cotton

amber

hard rubber

saran-wrap

teflon

THESE CHARGE NEGATIVE

(When rubbed on something higher)

Amber, or “Elektrum” from which we get “Electron” and “Electricity”

Modern Electricity

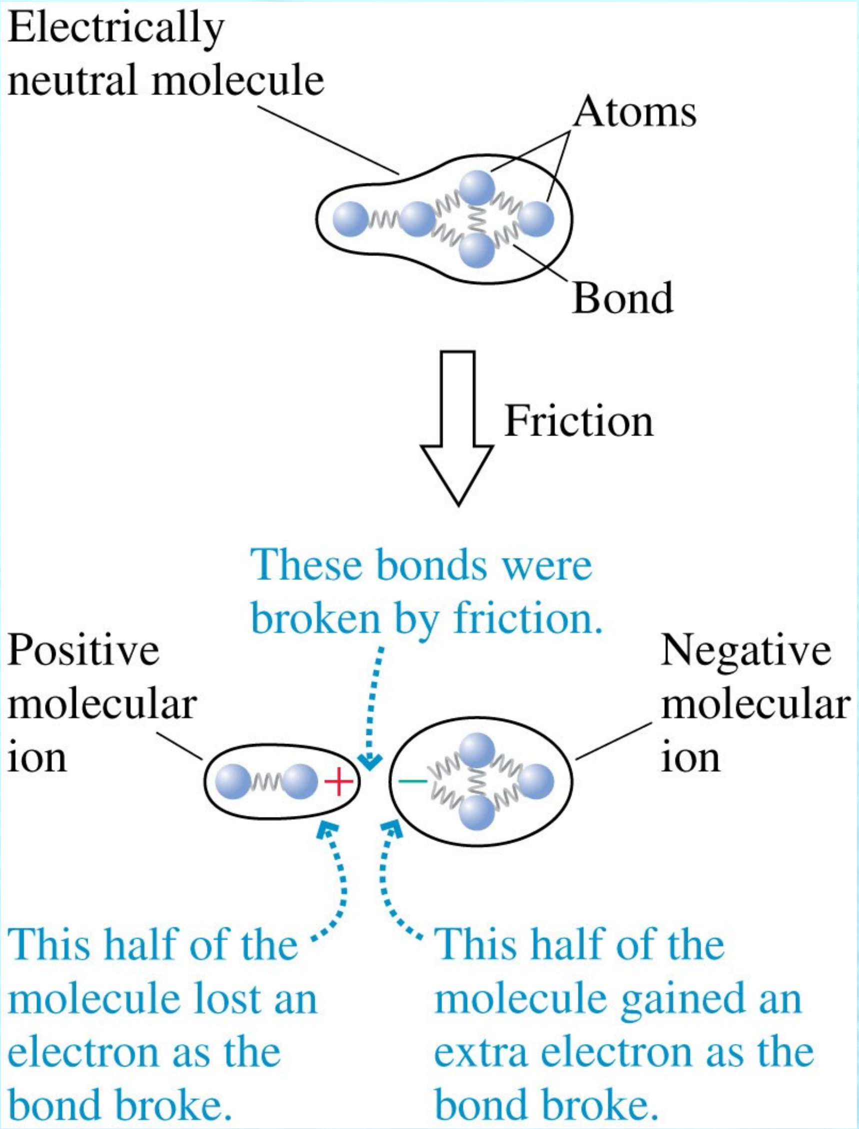
You can transfer charge to an insulator by spraying ions generated by a large electric field. (photocopiers / laser printers)

You can transfer charge
to a conductor by connecting it to another conductor at higher voltage.
(battery or power supply)

You can still do Ben Franklin things … rubbing breaks molecular bonds

How Tribocharging Works

- *Molecular ions* can be created when one of the bonds in a large molecule is broken.
- This is the way in which a plastic rod is charged by rubbing with wool or a comb is charged by passing through your hair.

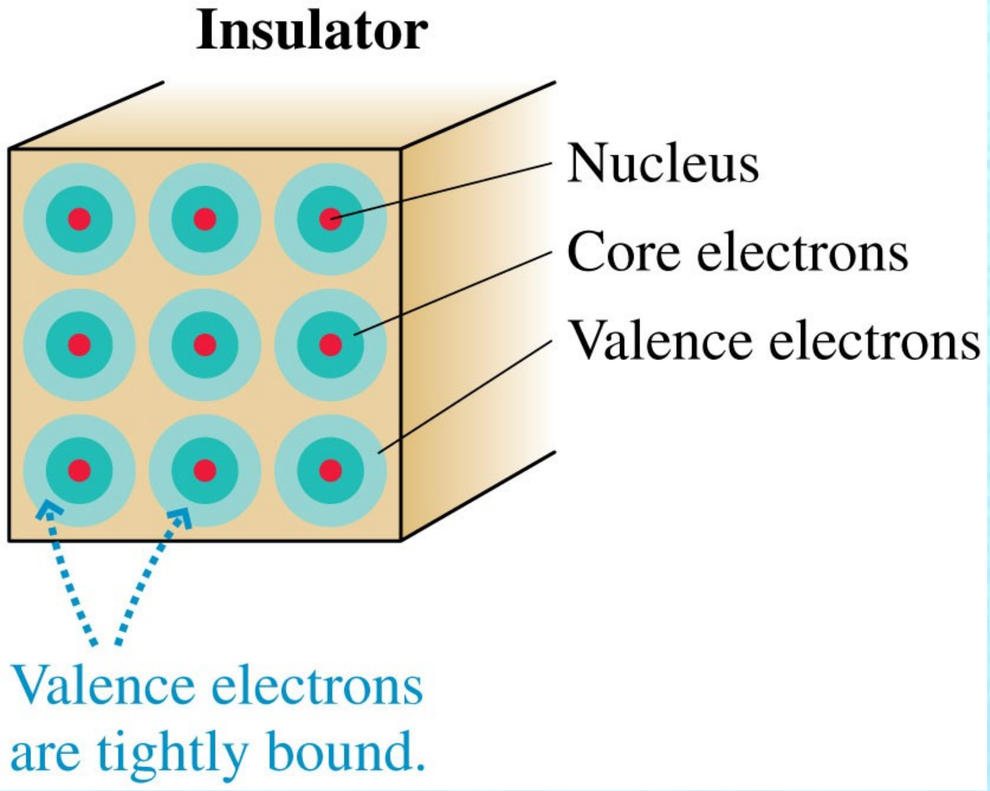


Insulators

- The electrons in an **insulator** are all tightly bound to the positive nuclei and

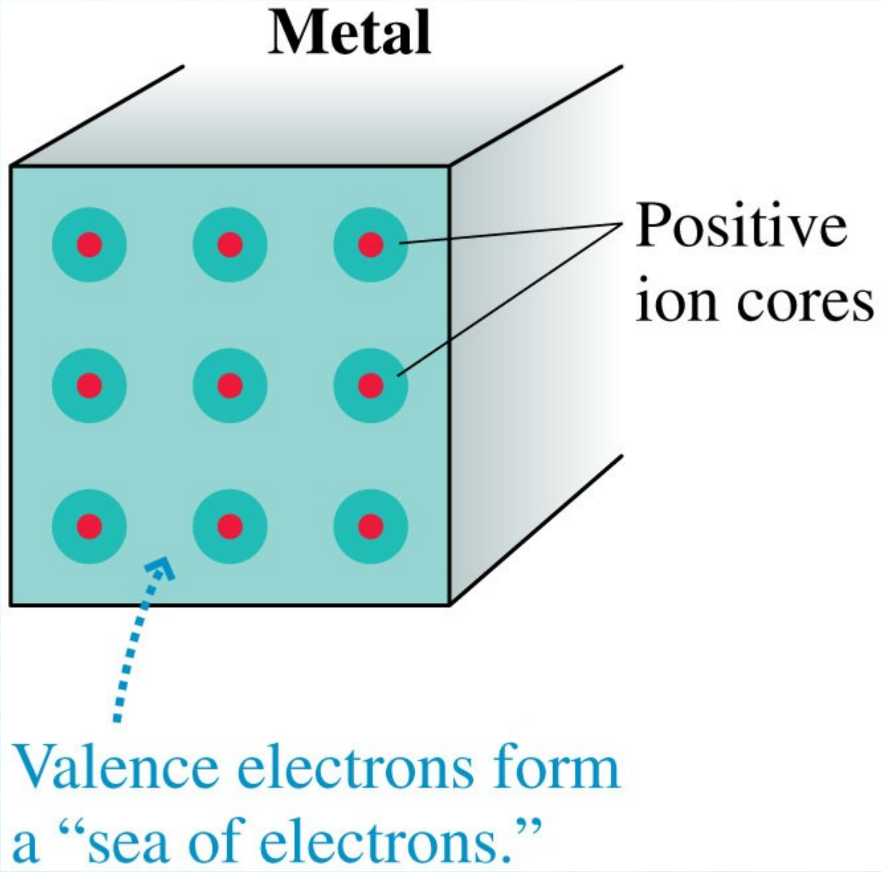
  not free to move around.

- Charging an insulator by friction leaves patches of molecular ions on the surface, but these patches are immobile.

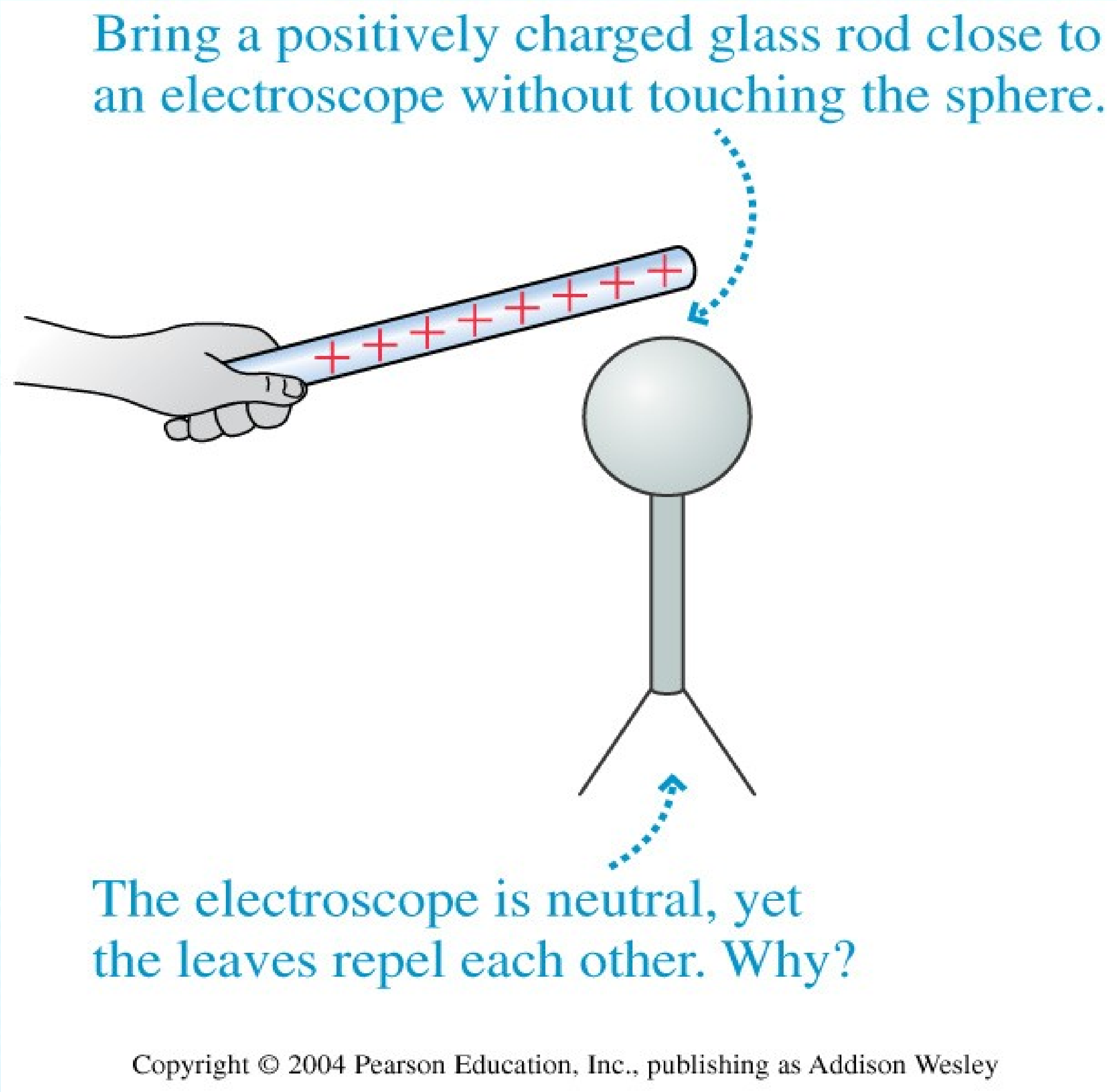


Conductors

- In metals, the outer atomic electrons are only weakly bound to the nuclei.
- These outer electrons become detached from their parent nuclei and are free to wander about through the entire solid.
- The solid *as a whole* remains electrically neutral, but the electrons are now like a negatively charged liquid permeating an array of positively charged **ion cores**.



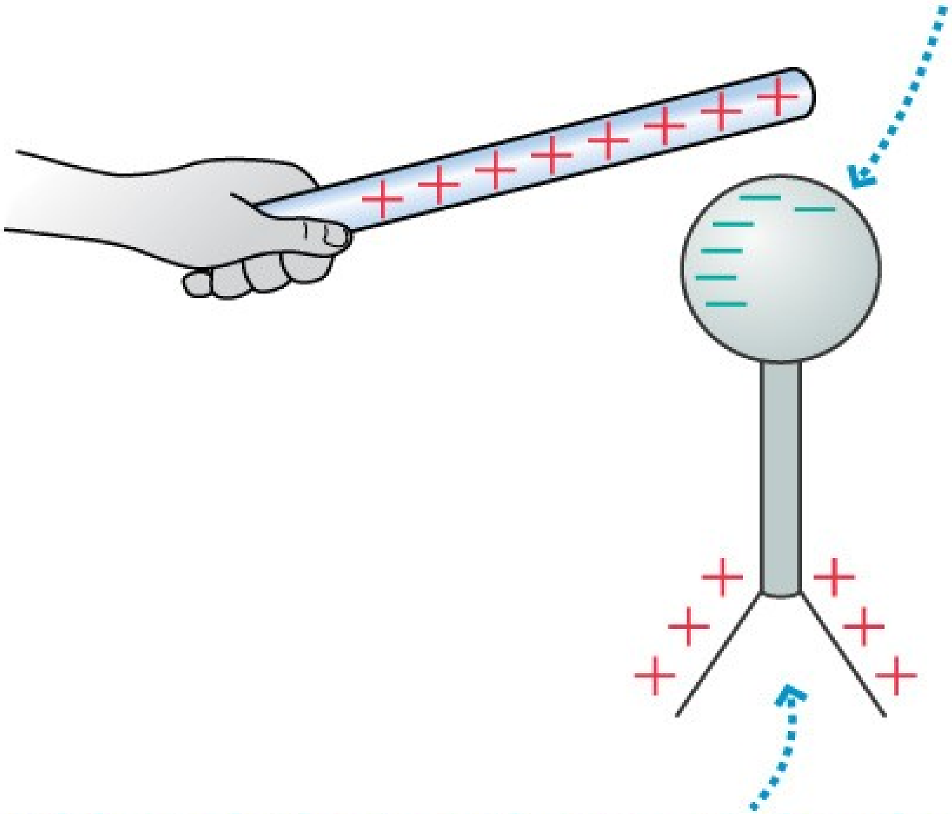
Electric Forces on Metals - I



Electric Forces on Metals - II

(b)

The electroscope is polarized by the charged rod. The sea of electrons shifts toward the rod.



Although the net charge on the electroscope is still zero, the leaves have excess positive charge and repel each other.

You rub a teflon with rabbits fur and make it negatively charged.

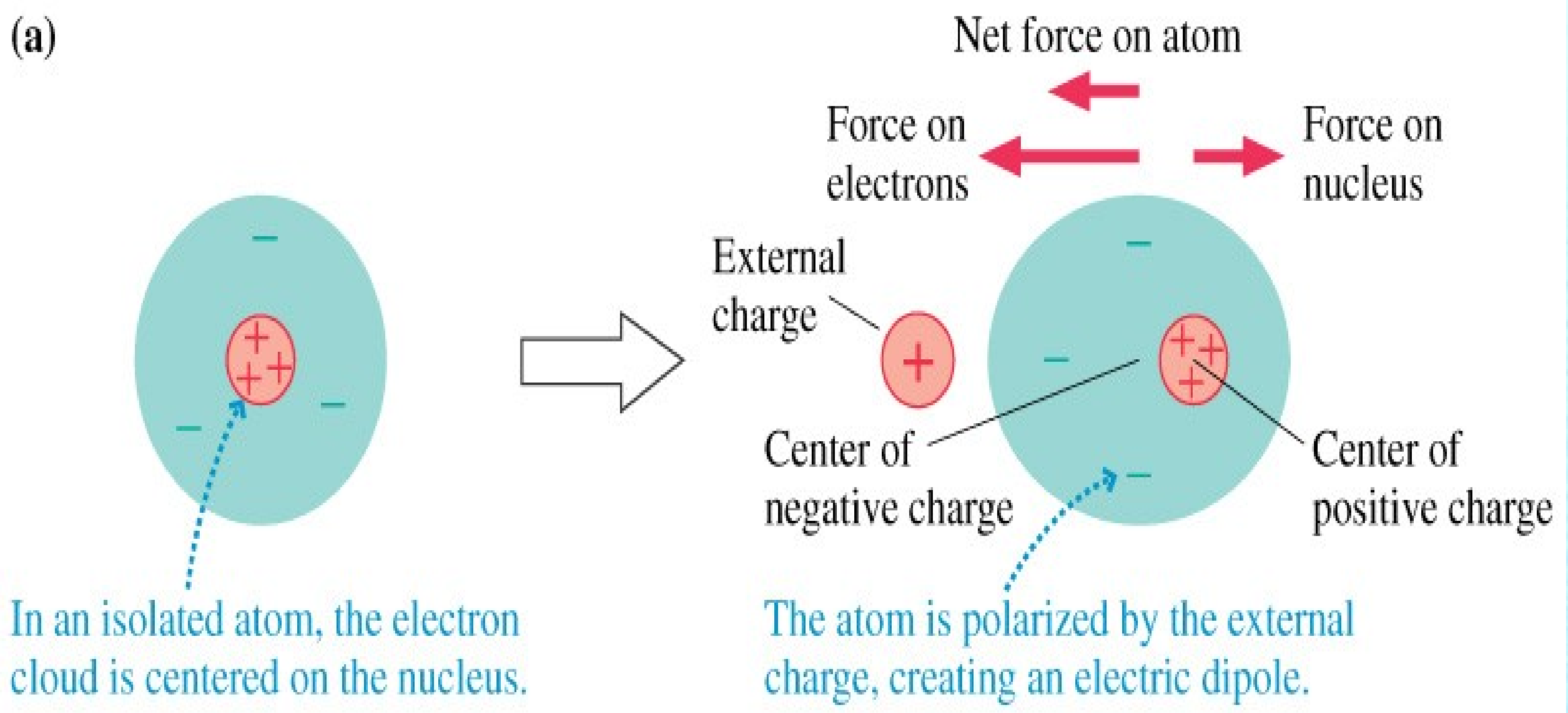
[A] The negatively charged teflon rod weighs slightly more than in did before it was rubbed and the rabbits fur a bit less.

[B] Neither material changes its weight.

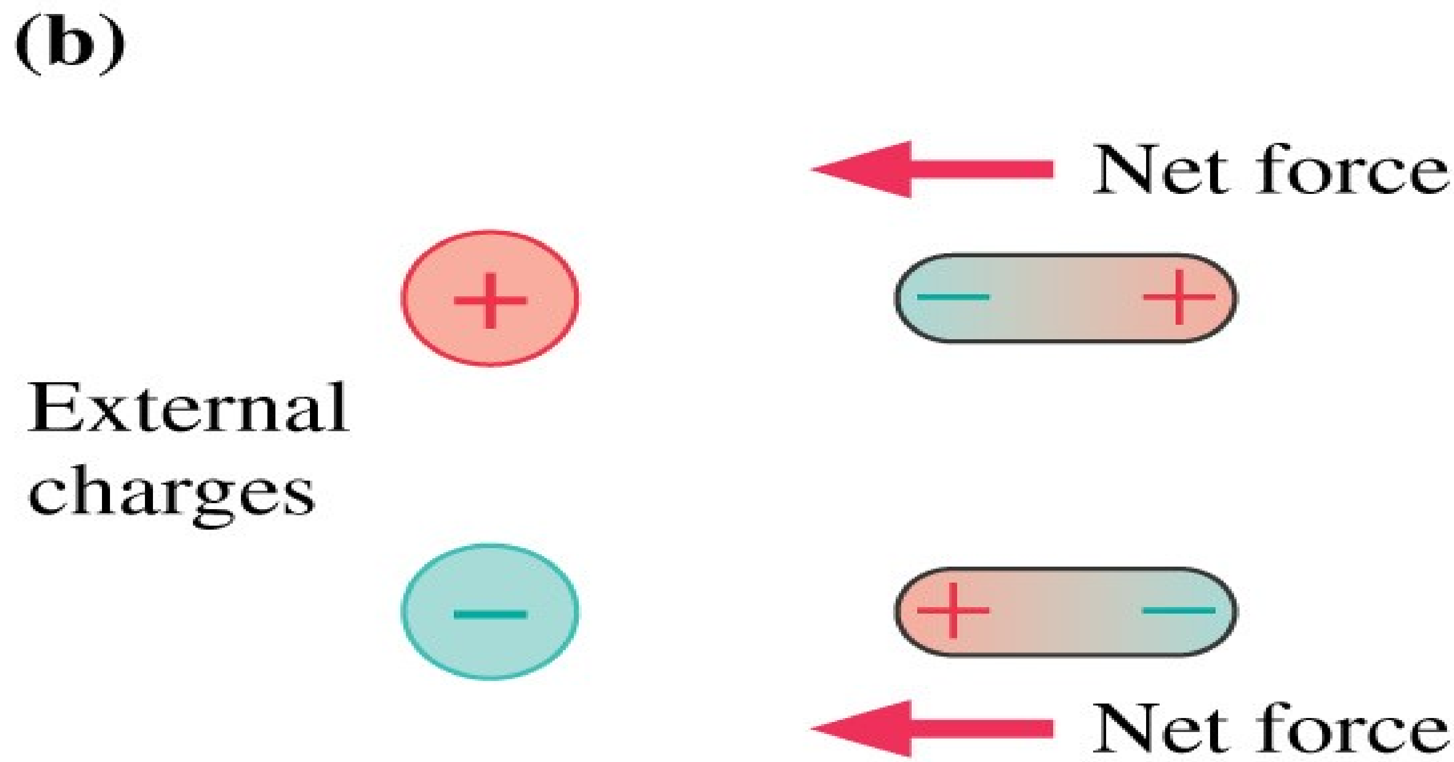
[C] Both materials are lighter than before

[D] The teflon is lighter than it was

Electric Forces on Insulators I



Electric Forces on Insulators II



Electric dipoles can be created by either positive or negative charges. In both cases, there is an attractive net force toward the external charge.

What is true?

[A] Only electrical conductors may be charged

[B] Only electrical insulators may be charged

[C] Both conductors and insulators may be charged

[D] You can't charge anything, only polarize it.

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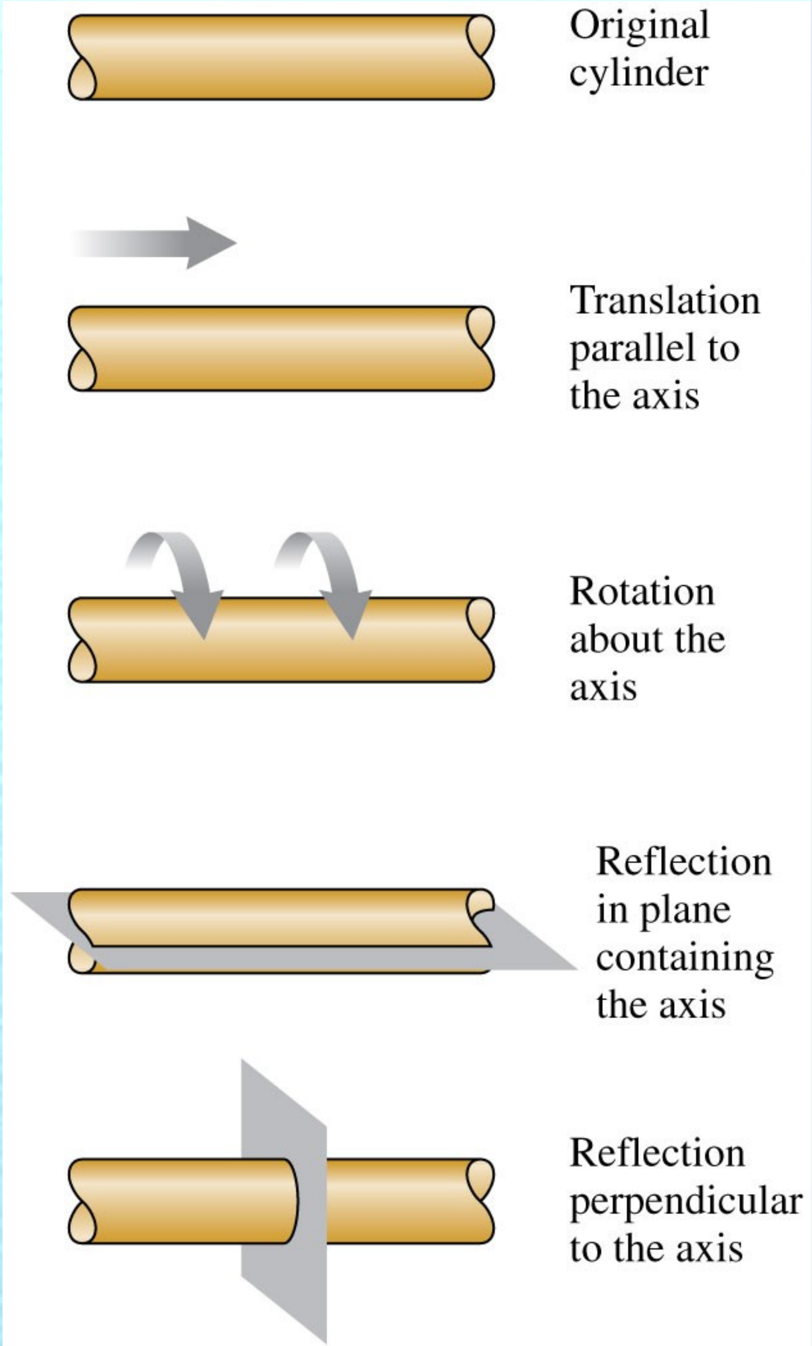
…symmetry

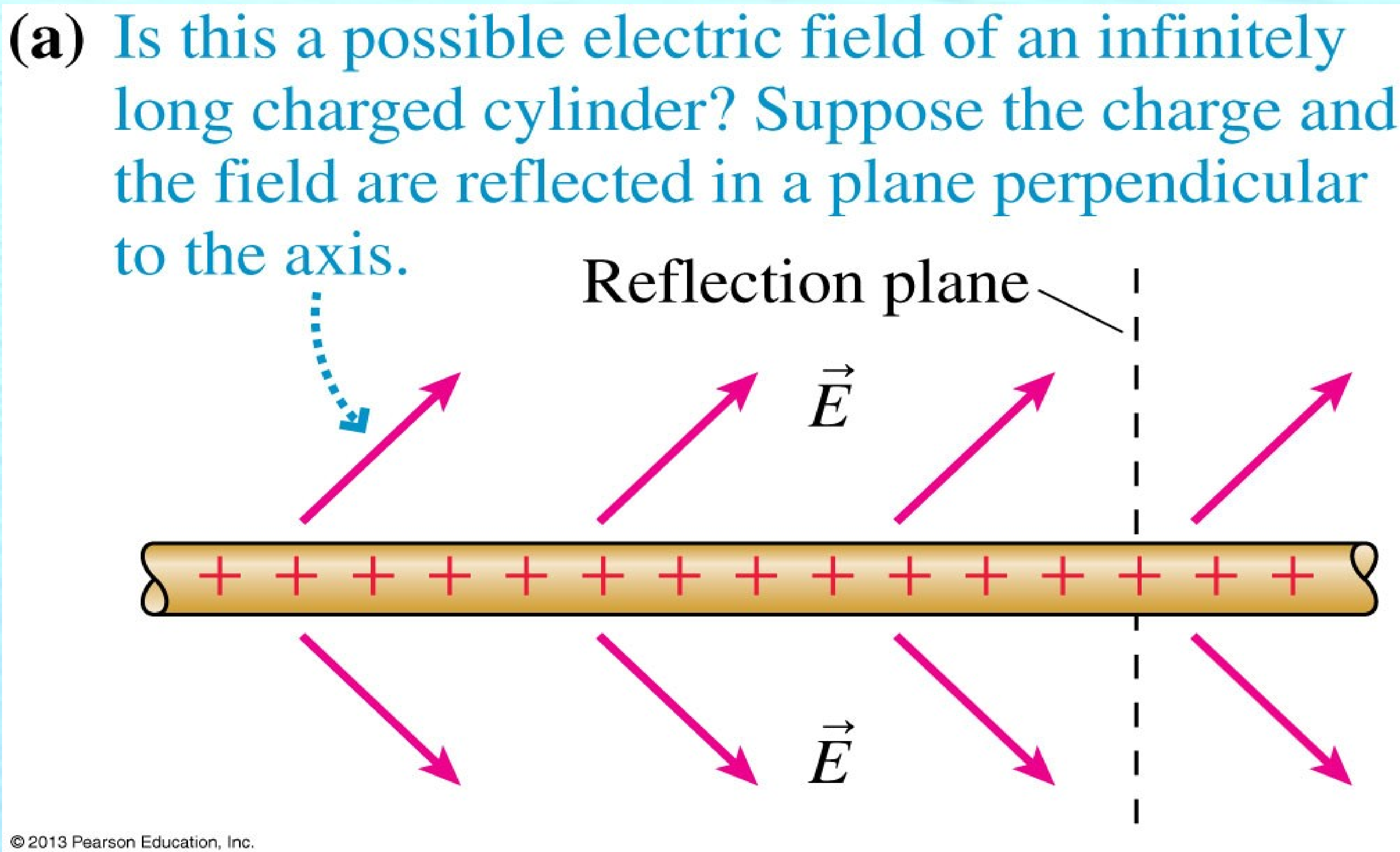
Relation between symmetry and Electric Field

If you can't physically tell where you are with respect to a charge, a line, or a surface (or any
Other charge distribution) then the Electric field direction cannot give you a hint.
Consider first an infinitely long cylinder.

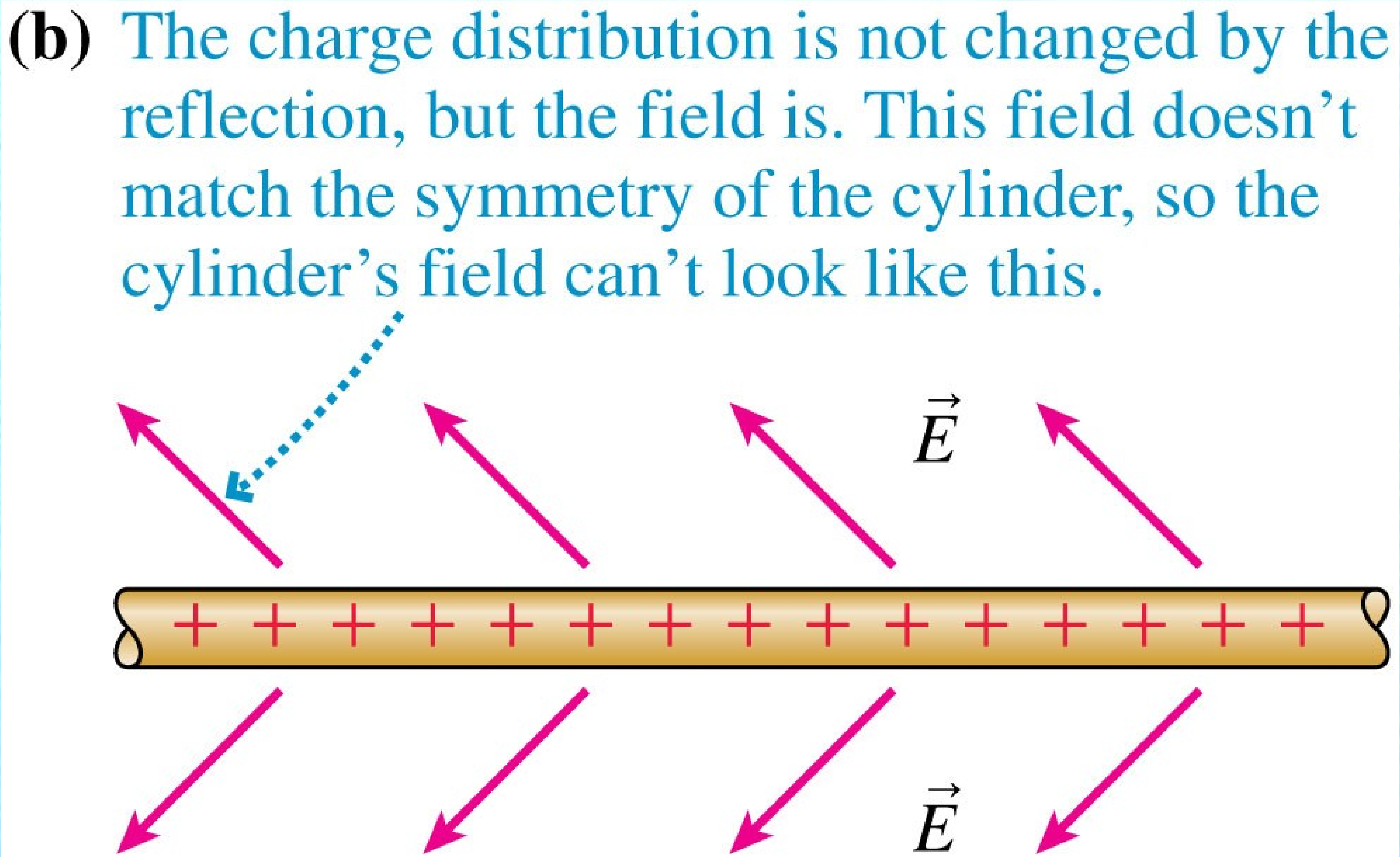
Relation between symmetry and Electric Field



Relation between symmetry and Electric Field



Relation between symmetry and Electric Field



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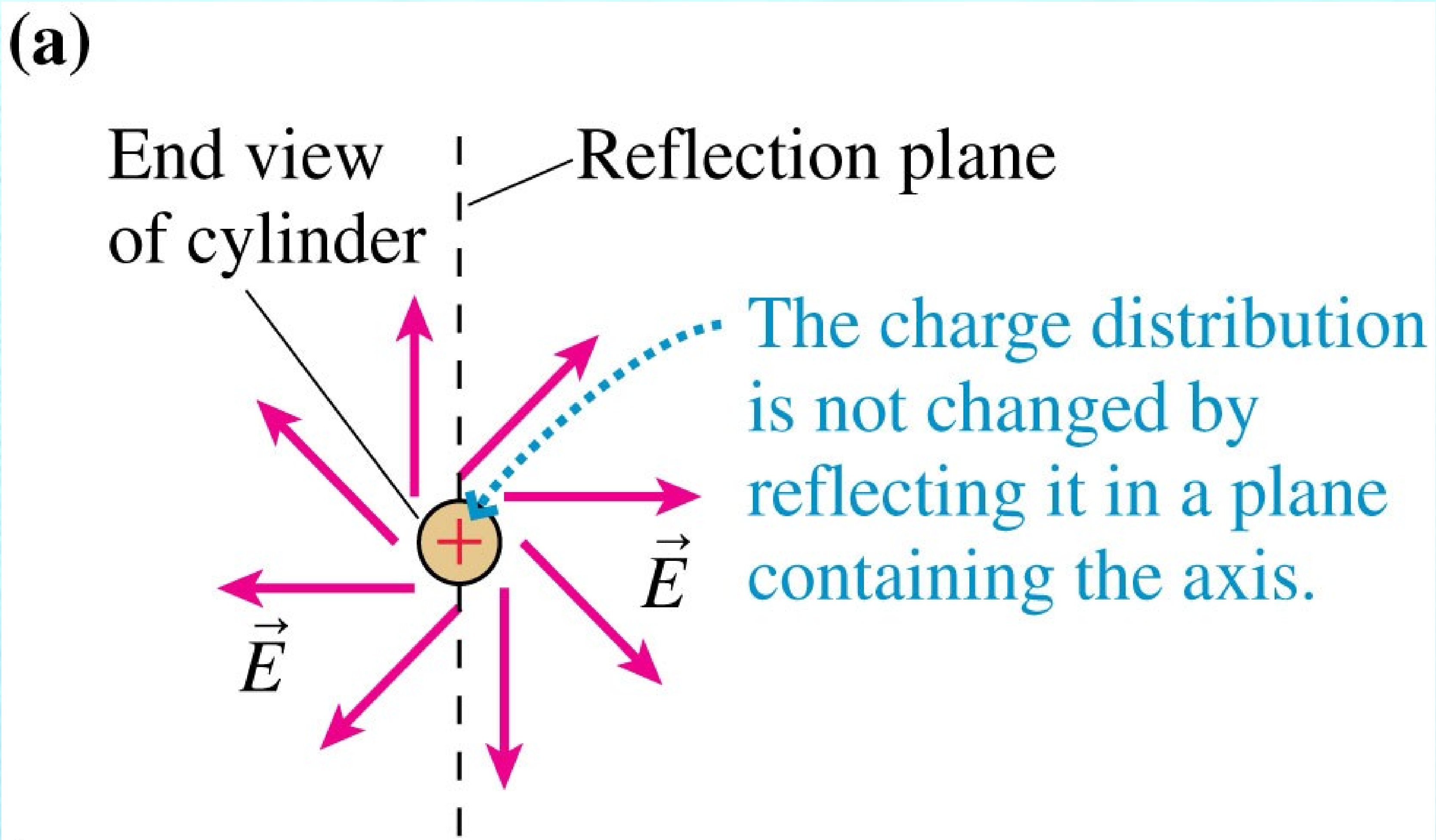

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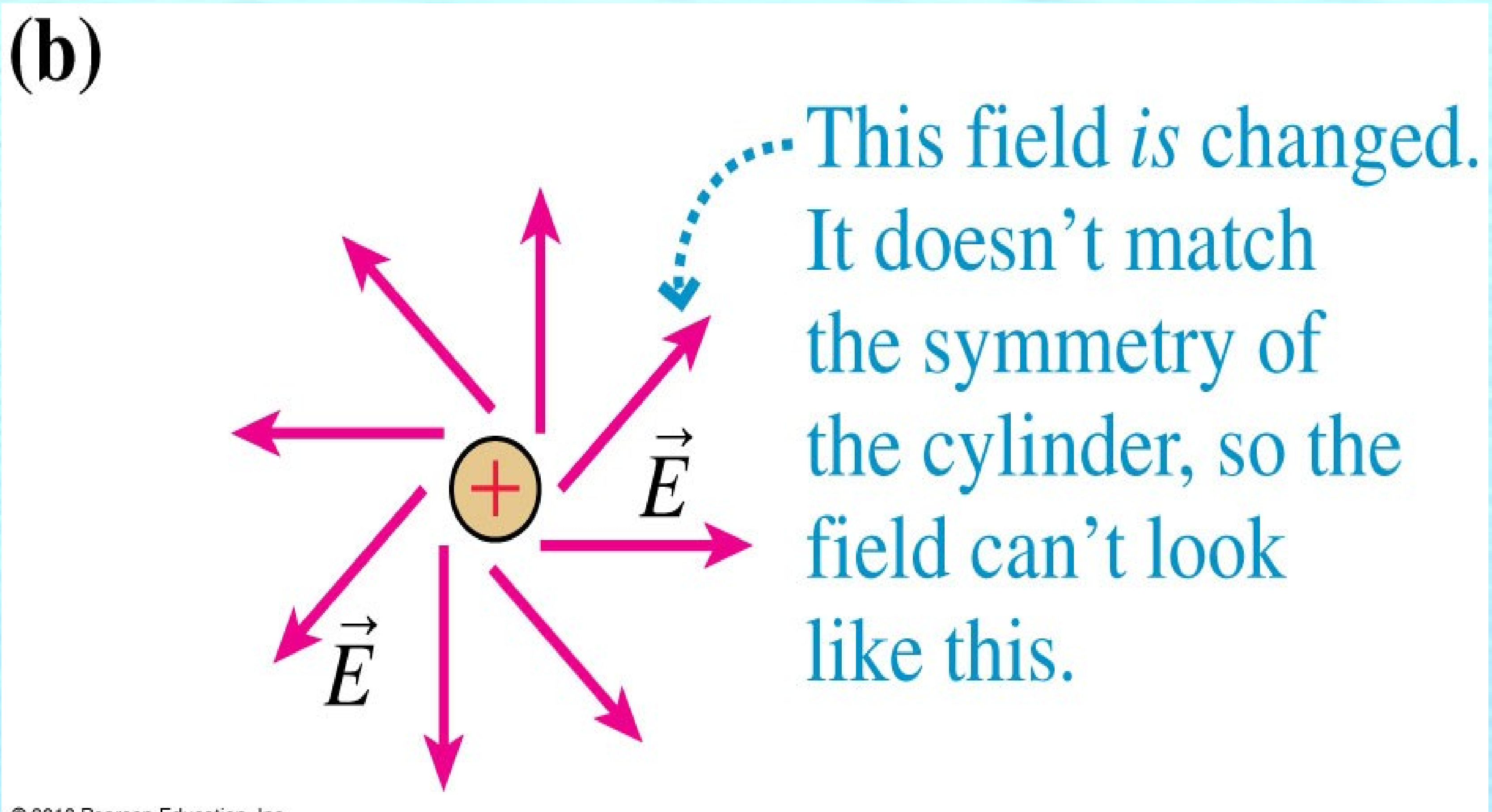
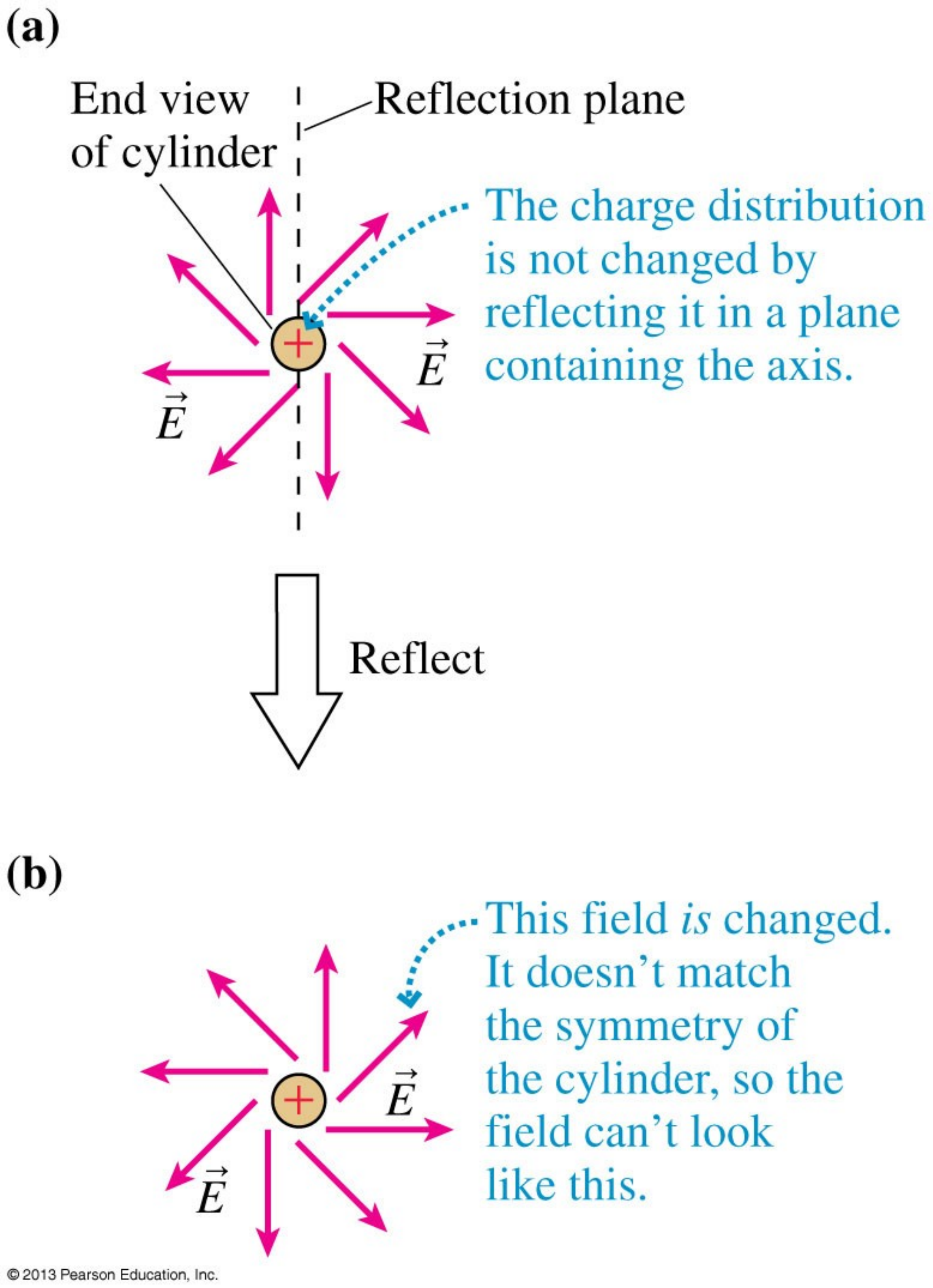
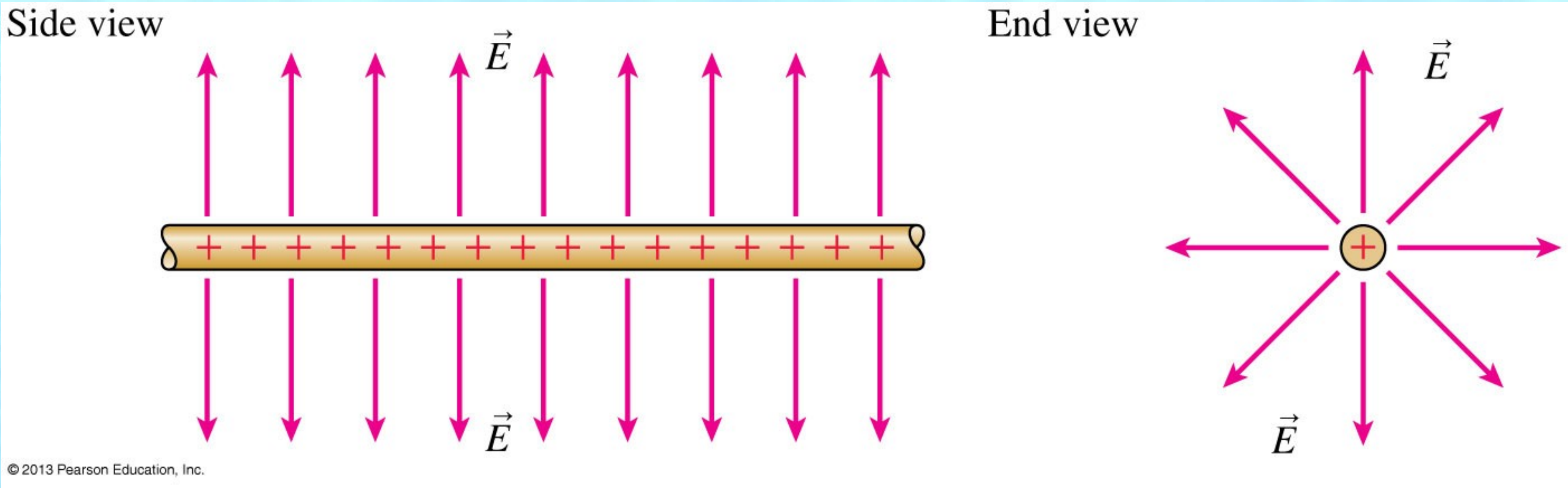


Relation between symmetry and Electric Field



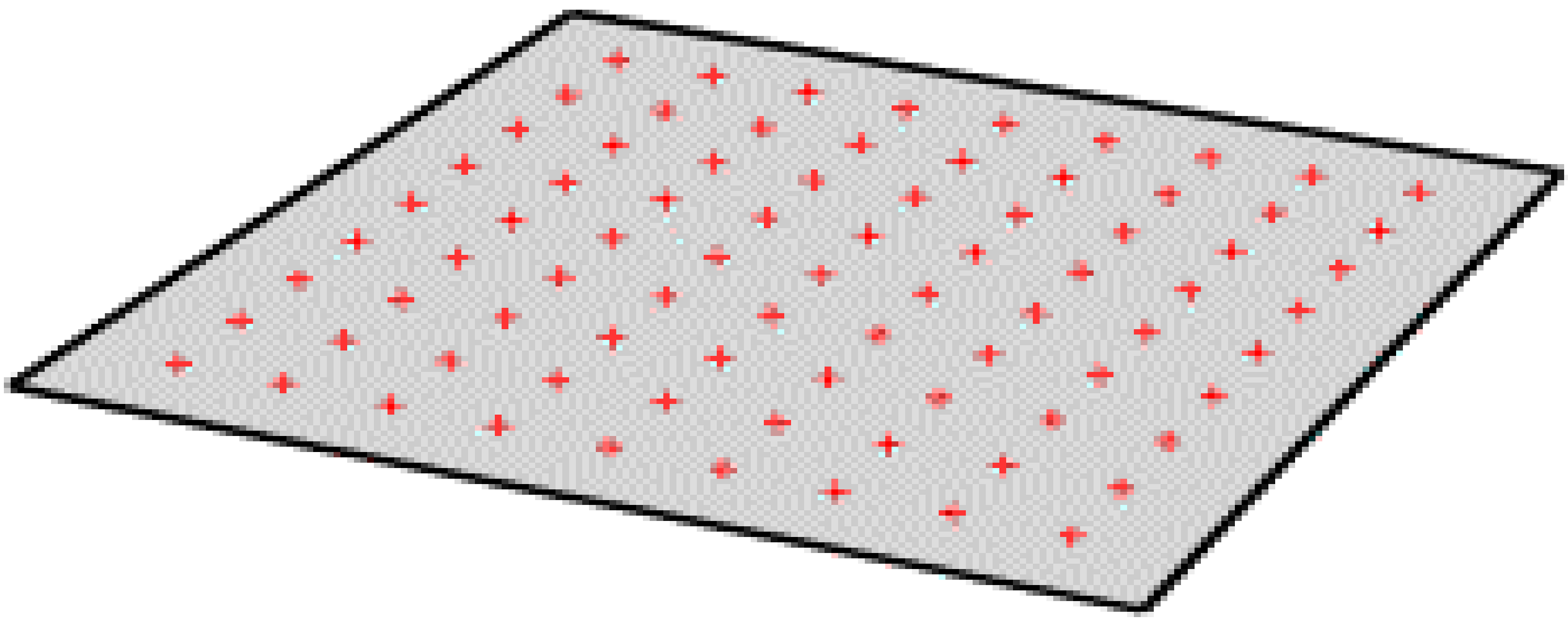
Relation between symmetry and Electric Field

The ONLY field consistent with symmetry of an infinitely long cylinder points radially outward.



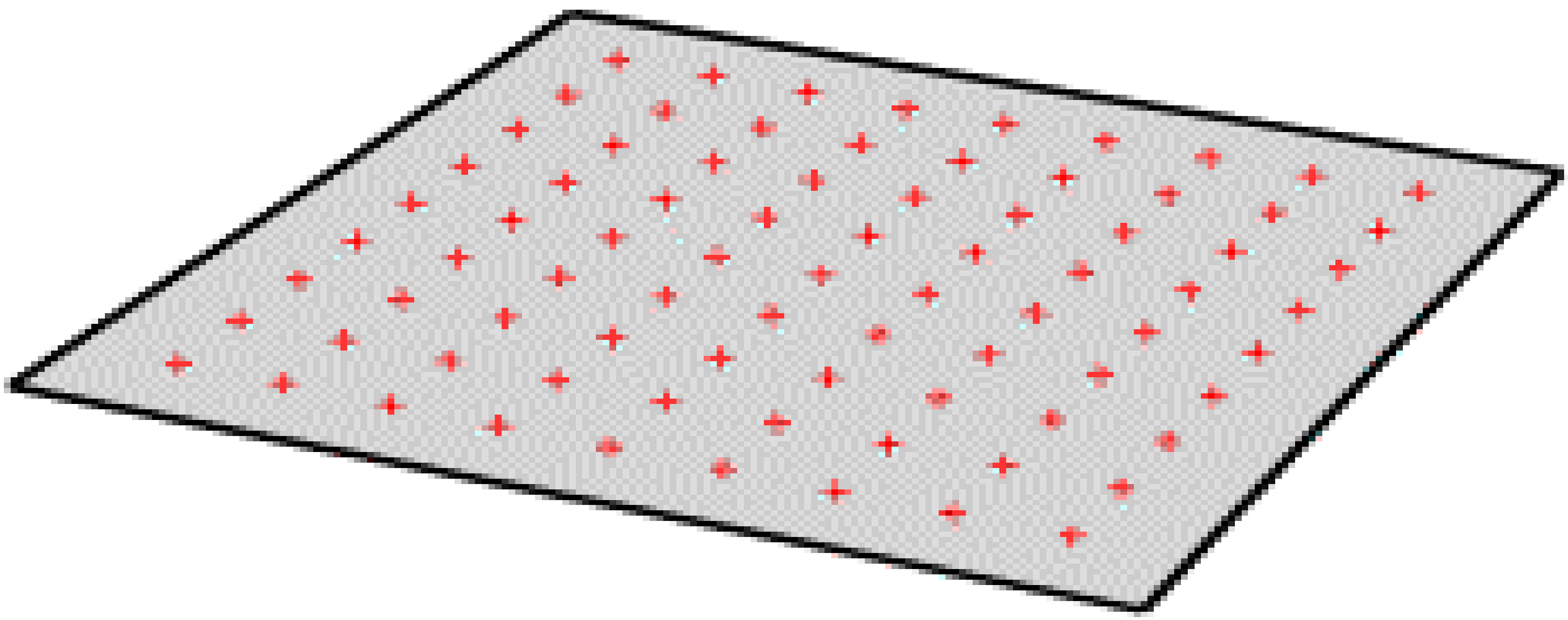
Relation between symmetry and Electric Field

Now imagine an infinite plane of charge.



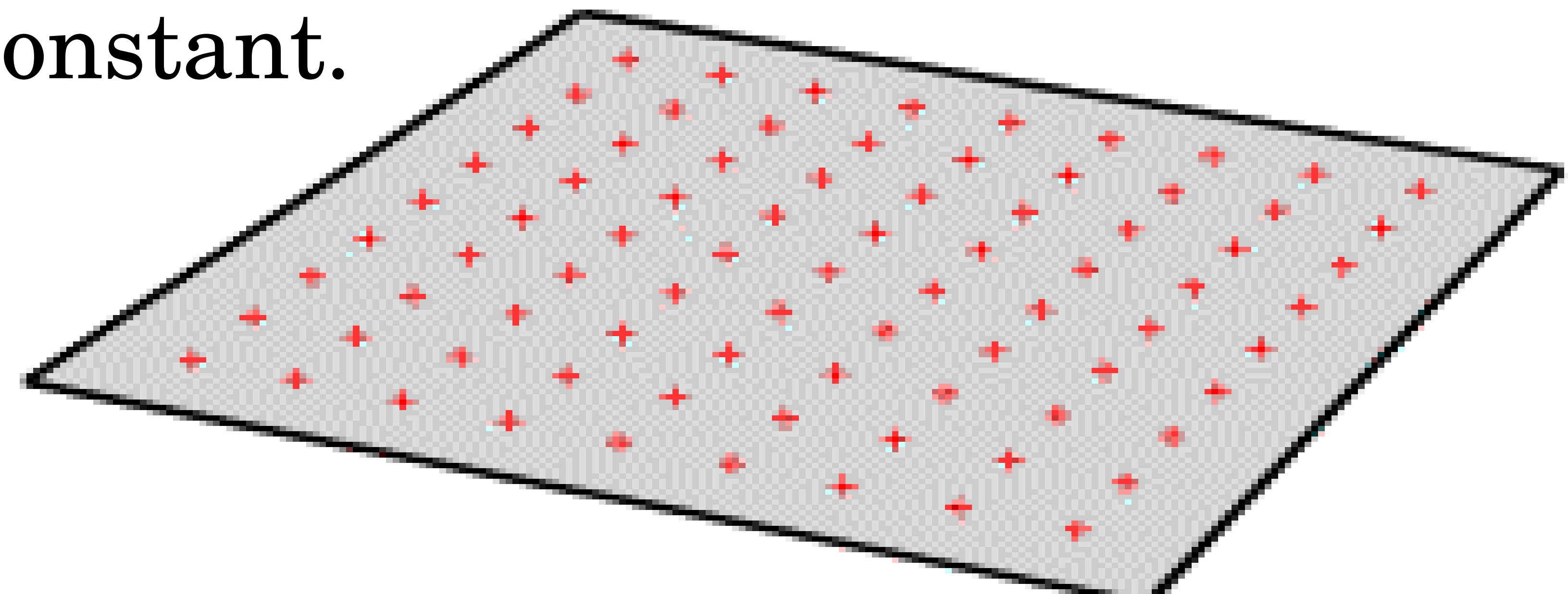
Relation between symmetry and Electric Field

Because you can't tell what direction you are facing, the field must be ONLY Perpindicular to the plane.



Relation between symmetry and Electric Field

Because you ALSO can't tell how far away you are from the plane, the field cannot change magnitude. It must be constant.



$$\vec{E} = \frac{\sigma}{2\epsilon_0}\hat{j} \qquad \vec{E} = \frac{\lambda}{2\pi r \epsilon_0}\hat{r} \qquad \vec{E} = \frac{Q}{4\pi r^2 \epsilon_0}\hat{r}$$