Physics 122 – Class #16 – Outline

- Announcements
- Field of continuous charge distributions (by symmetry)
- Worked Problems
- Derivation of field of a line
- Equipotentials (next week's lab)

Readings

Read Chapter 28 for next week. Omit 28.3

Test #2 – Thursday 3/12

Chapters 25, 26 …

Look for additional homework and practice questions on chapter 26.

Test will cover lectures up through Tuesday 3/10.

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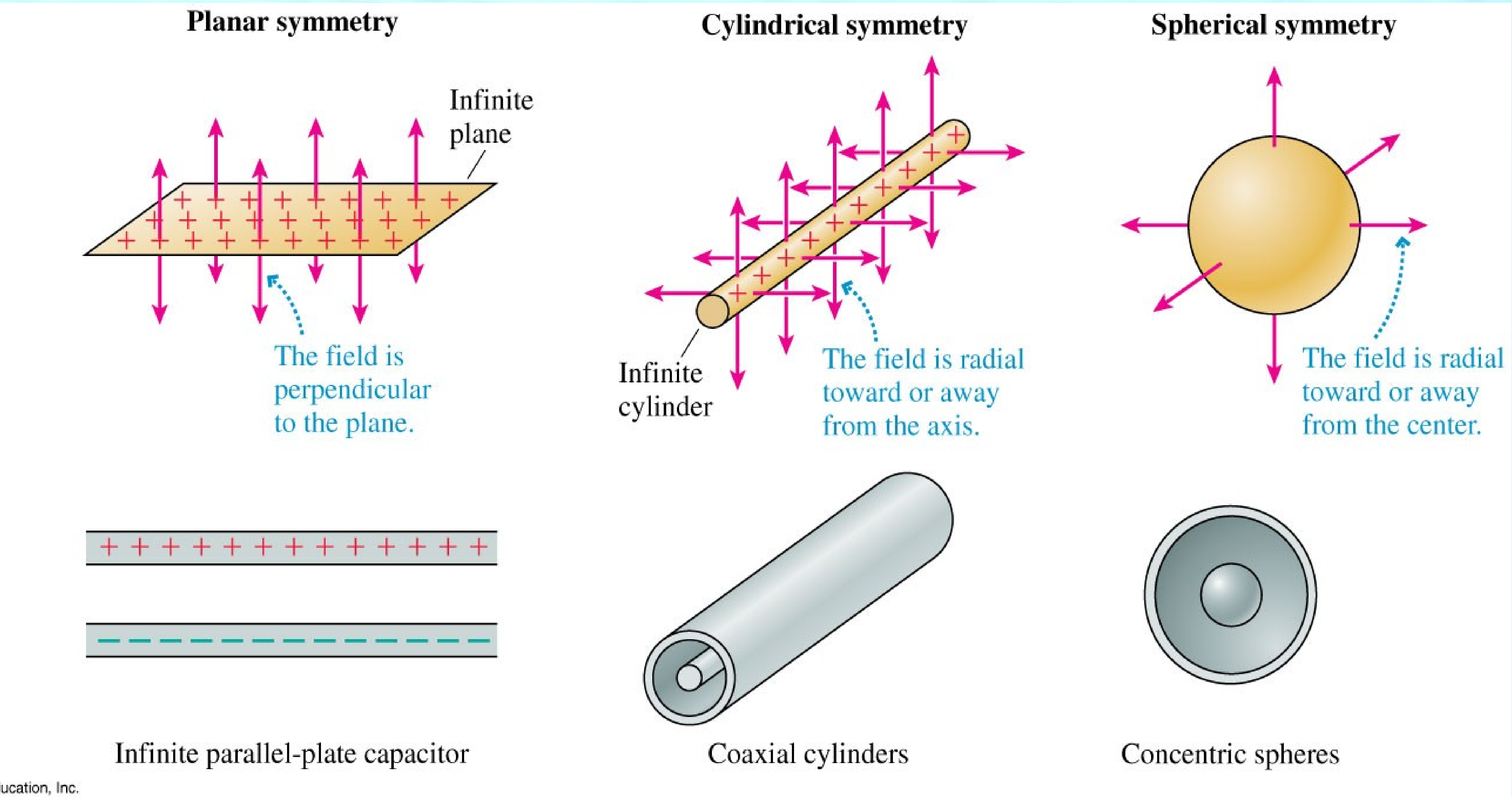
$$\vec{E} = \frac{\sigma}{2\epsilon_0}\hat{n}$$

$$\vec{E} = \frac{\lambda}{2\pi r \epsilon_0}\hat{r}$$

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



Field near a “large” vertical uniform sheet of charge

$$\vec{E}=\frac{\sigma}{2\epsilon_0}\hat{n} \qquad \sigma=\frac{Q}{A}$$

Field outside of a “long” line of charge.

$$\vec{E}=\frac{\lambda}{2\pi r\epsilon_0}\hat{r} \qquad \lambda=\frac{Q}{L}$$

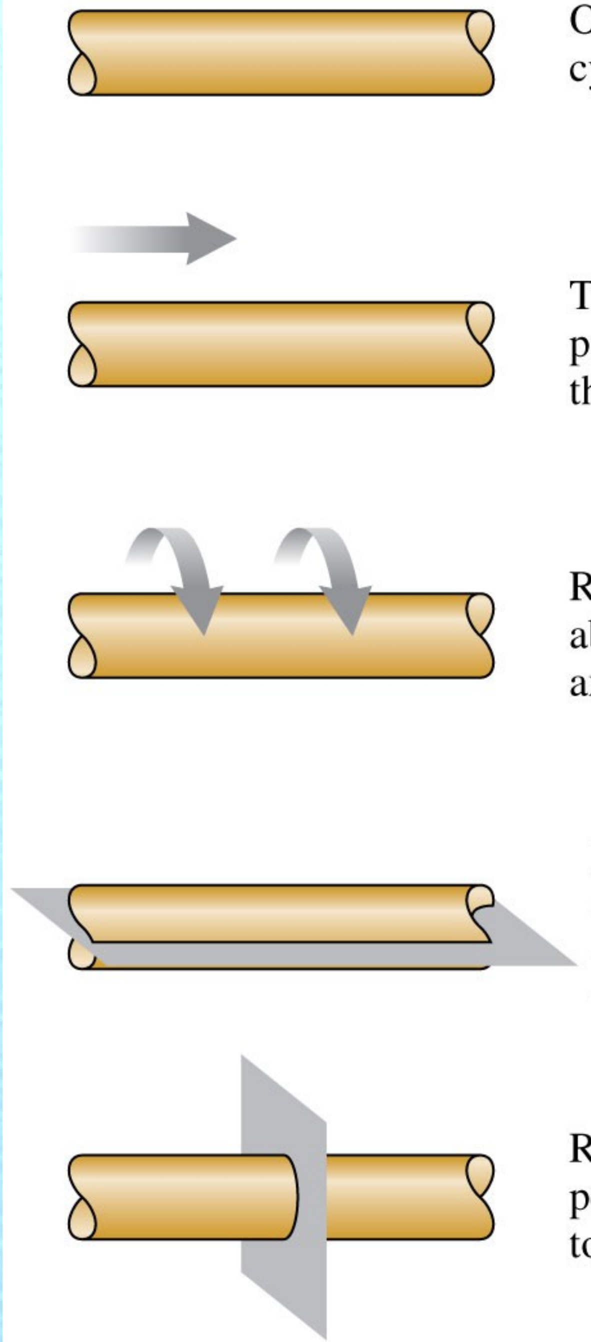
Field outside of a uniform sphere of charge Q.

$$\vec{E}=\frac{Q}{4\pi r^2\epsilon_0}\hat{r} \qquad \rho=\frac{Q}{V}$$

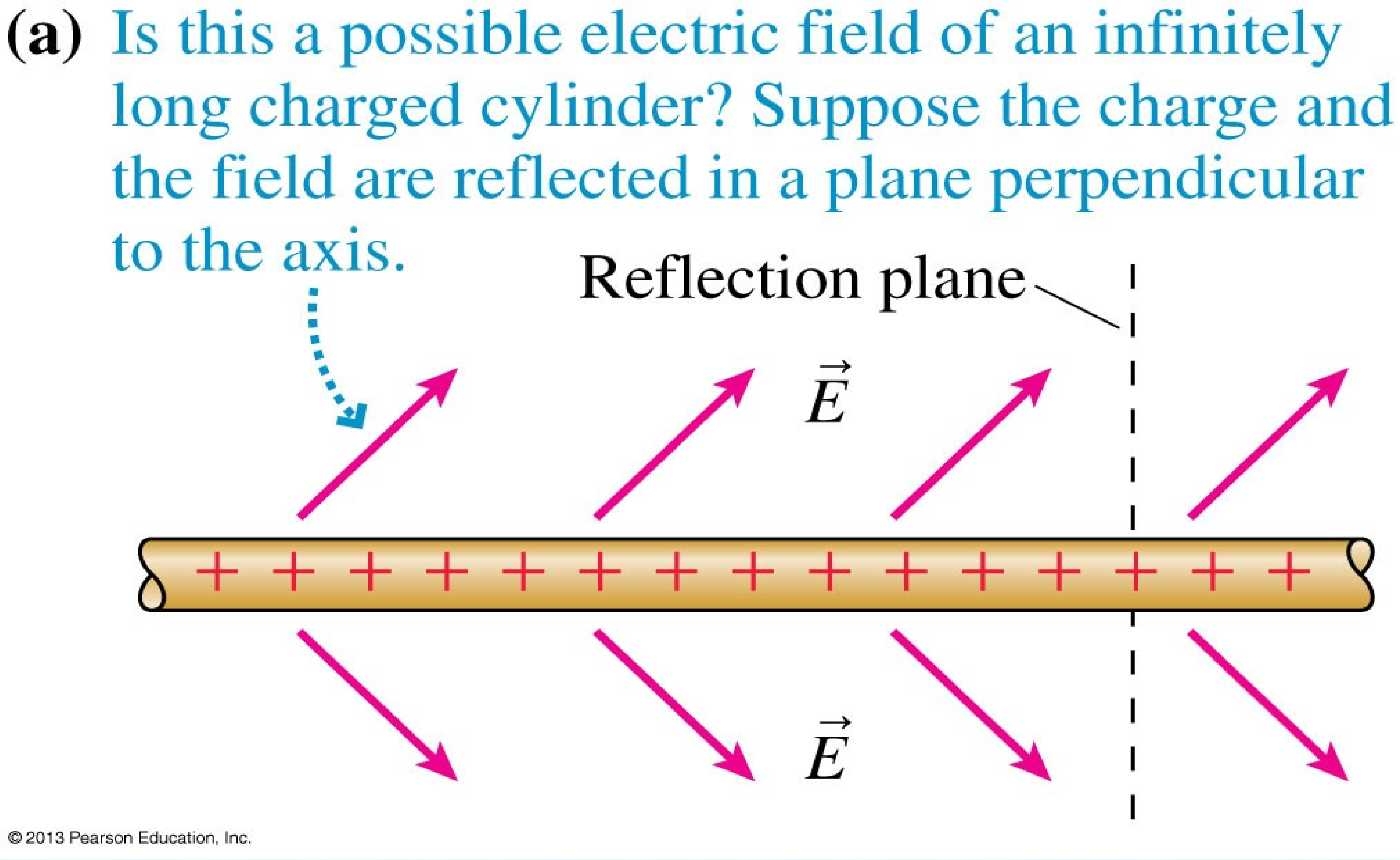
Estimating Electric Field using symmetry arguments

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.

Estimating Electric Field of Cylinder using symmetry arguments

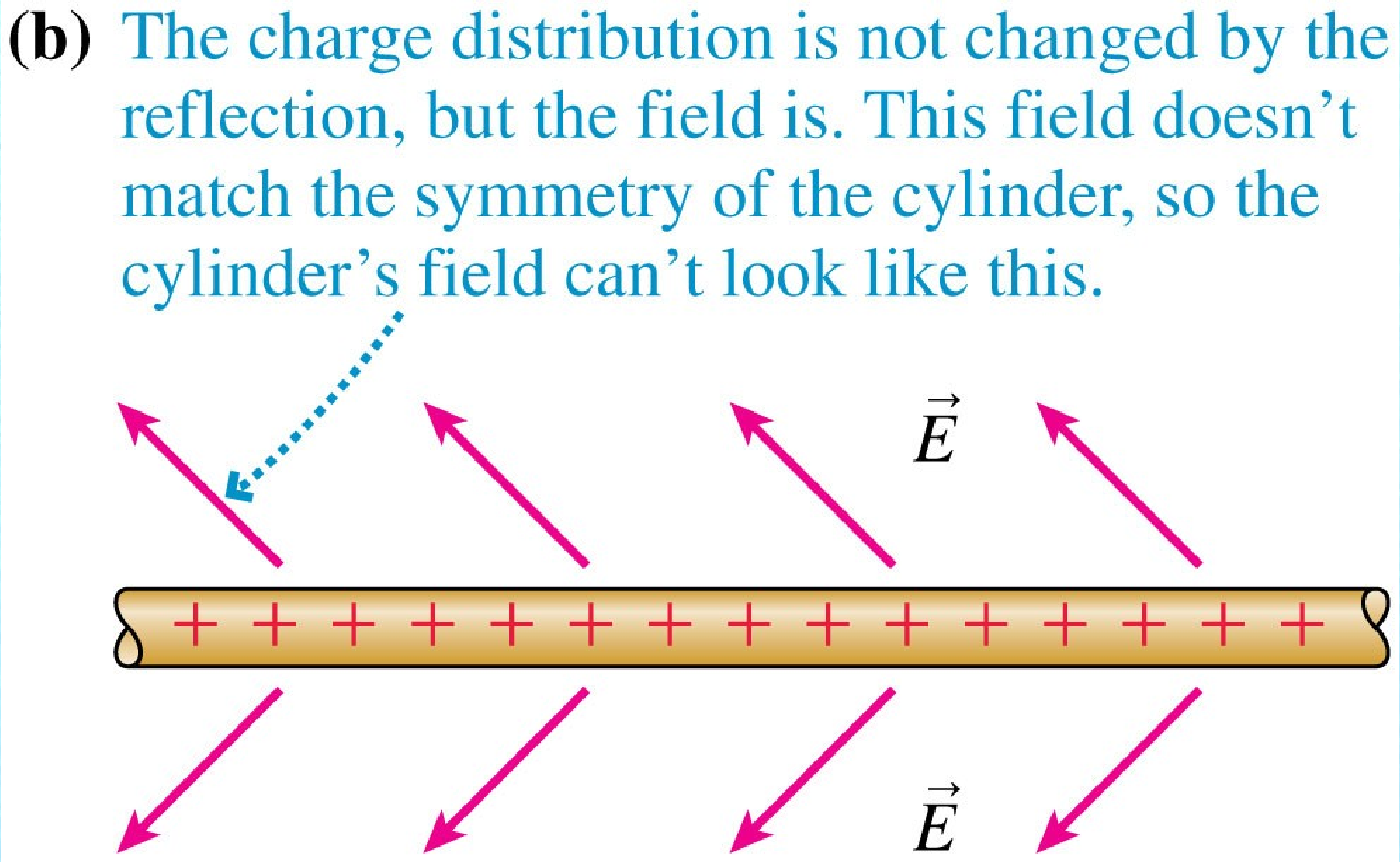


Electric Field of cylinder - A

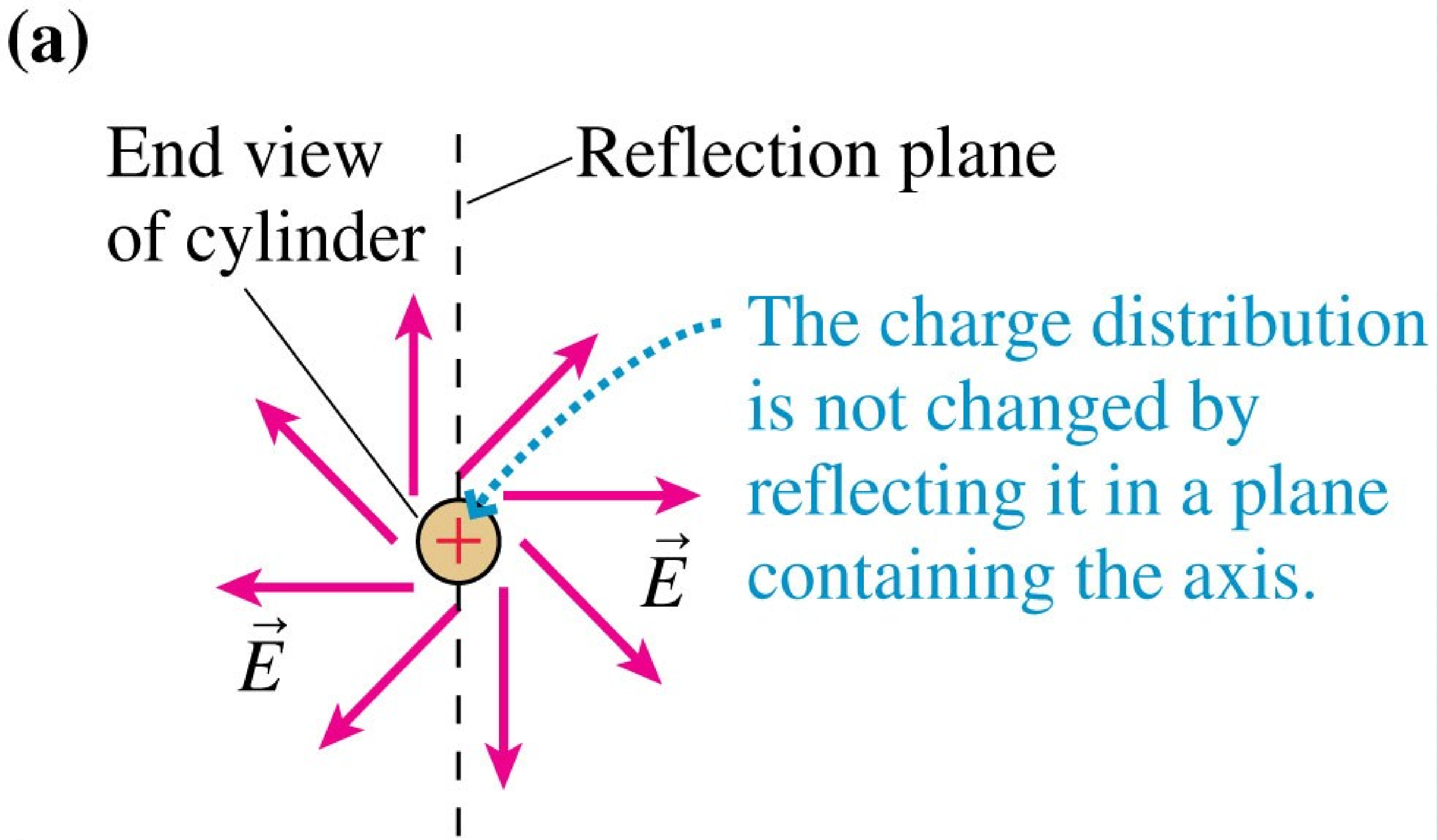


Electric Field of cylinder – B

There can't be a component along axis

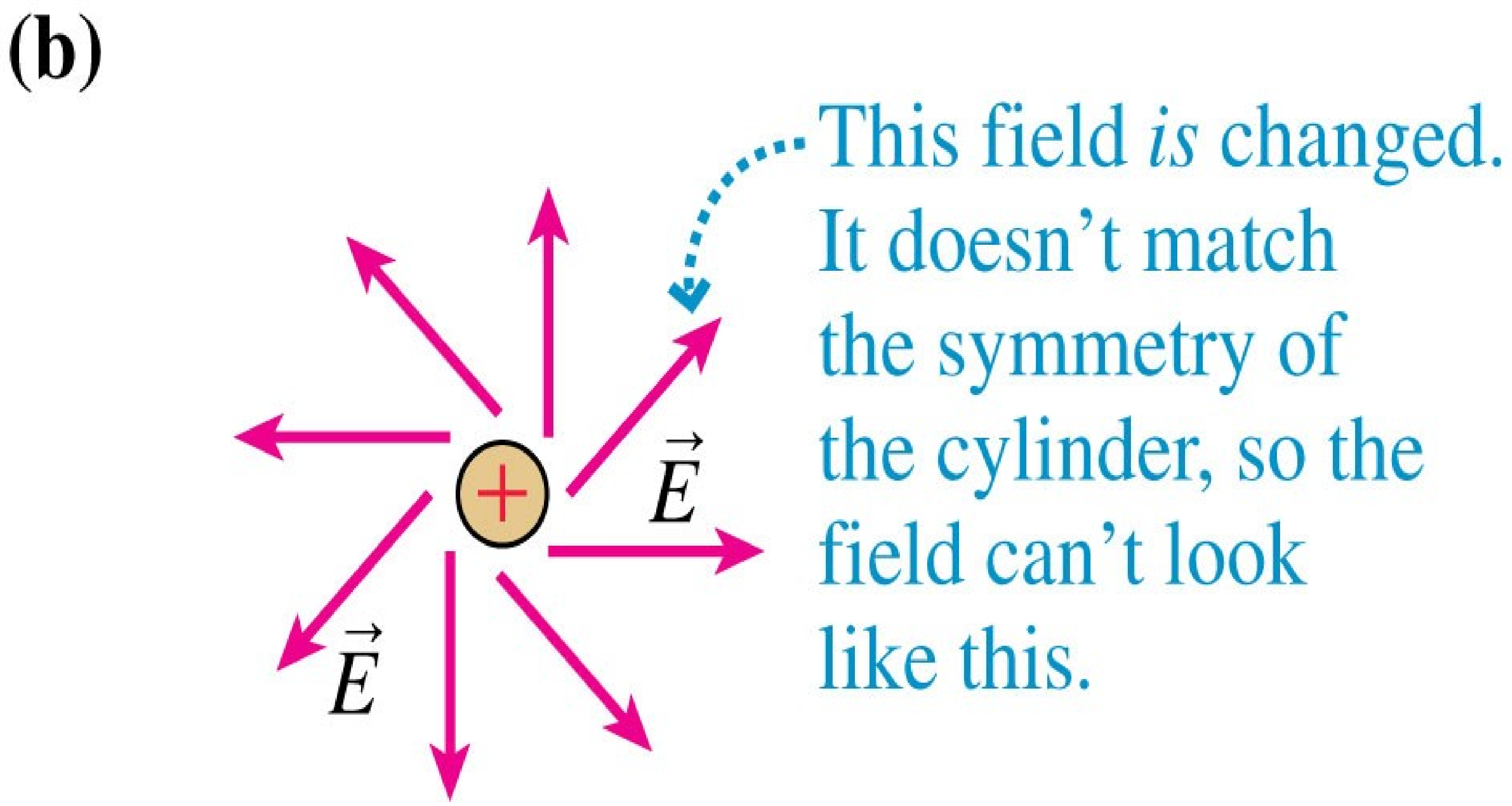


Electric Field of cylinder – C



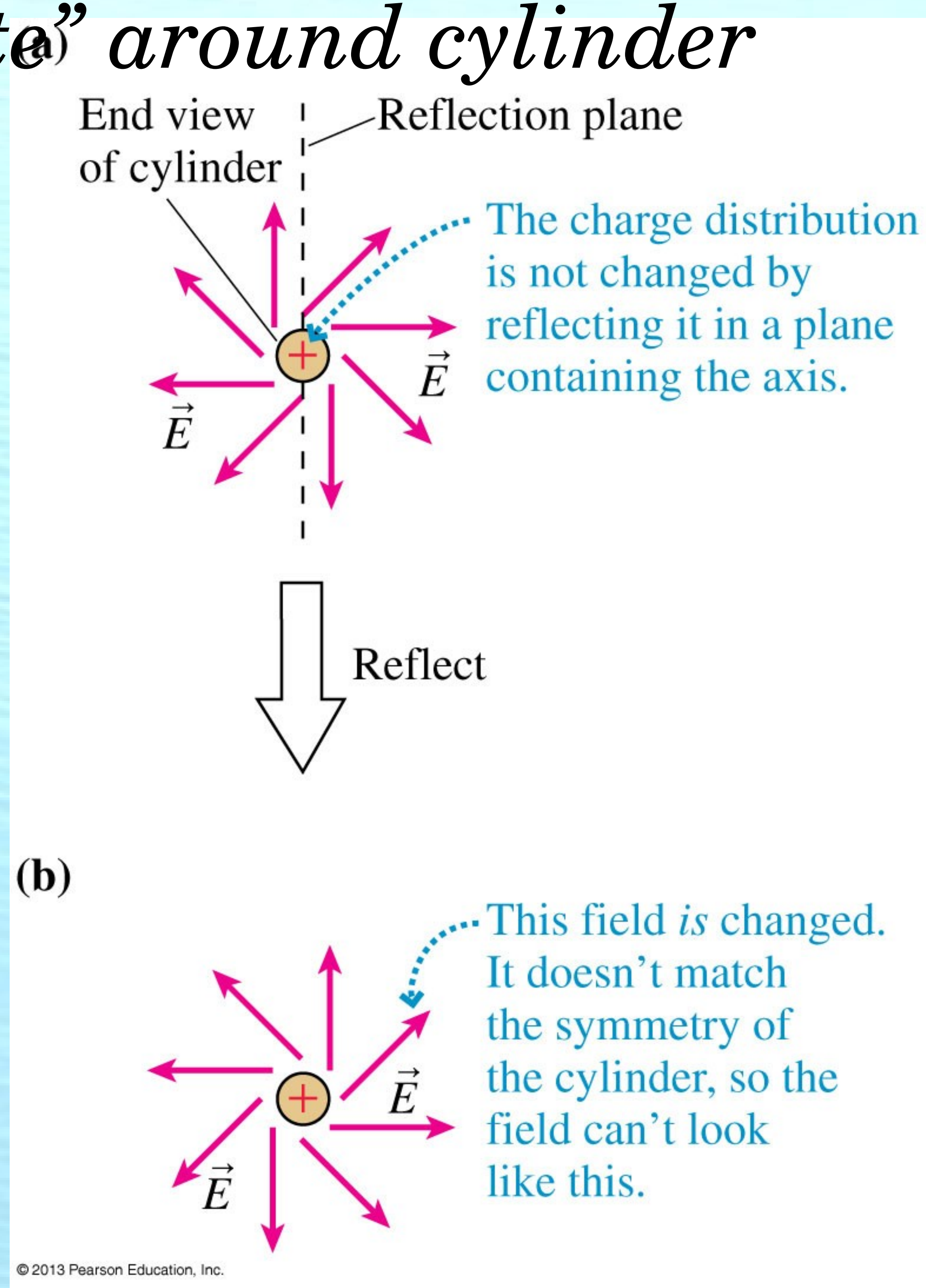
Electric Field of cylinder – D

The field cannot "rotate" around cylinder



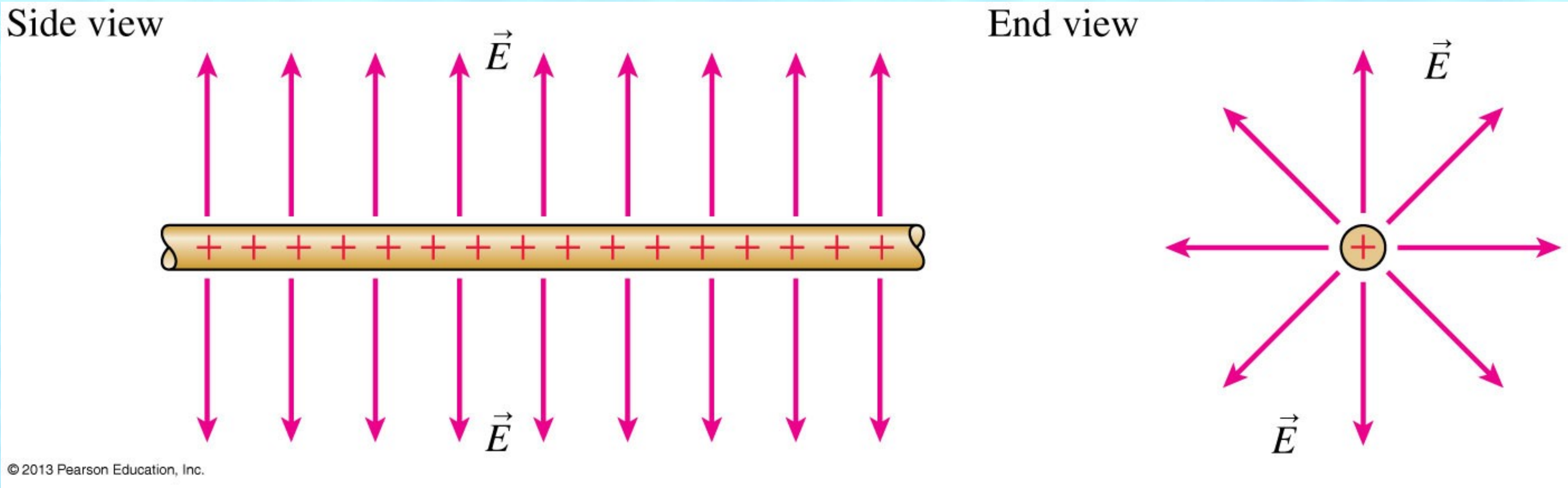
Electric Field of cylinder – E

The field cannot "rotate" around cylinder



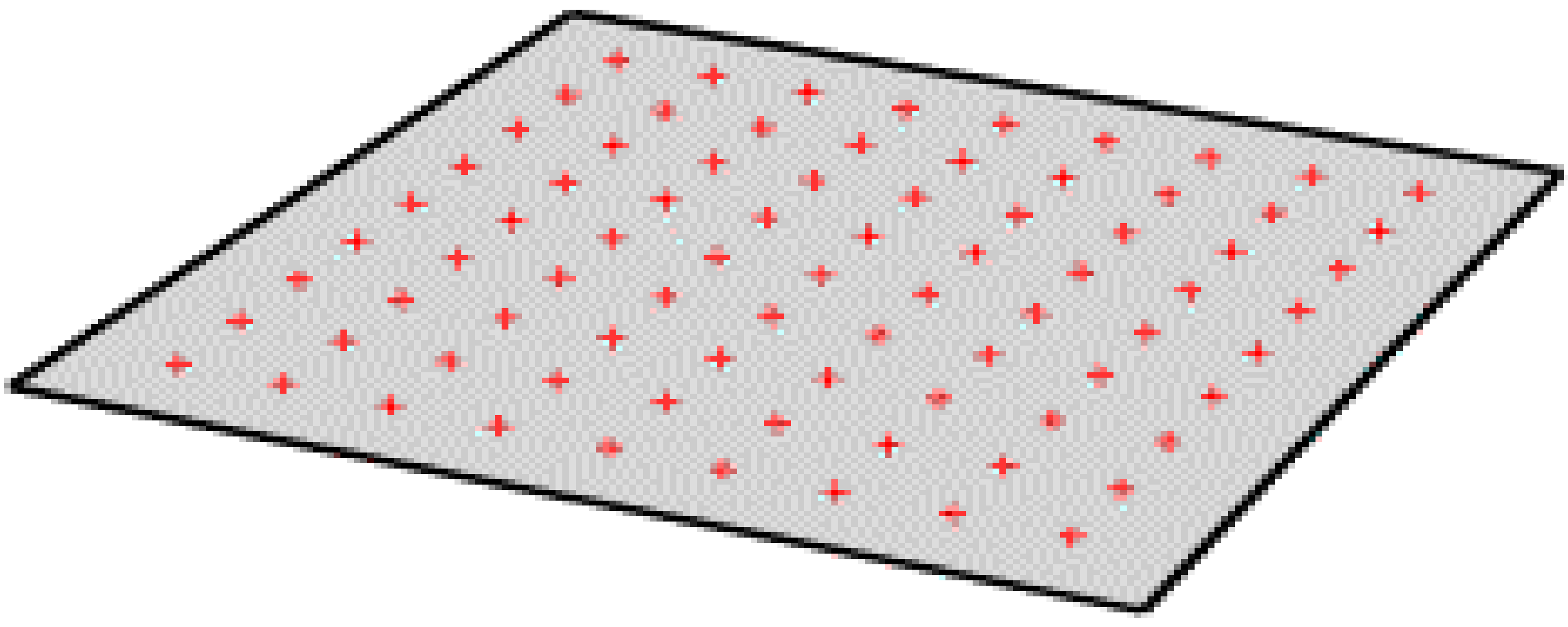
Electric Field of a cylinder

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



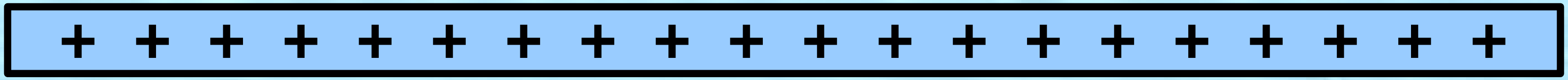
Electric Field of a plane of charge

Now imagine an infinite plane of charge.



Direction of Electric Field of a plane of charge

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



How large is this picture?

[A] It's a part of a bathroom Floor (4'x6')

[B] It is a part of an oil painting 12” x 18”

[C] It is the floor of a warehouse 50'x75'

[D] It is an abandoned airfield 1000'x1500'

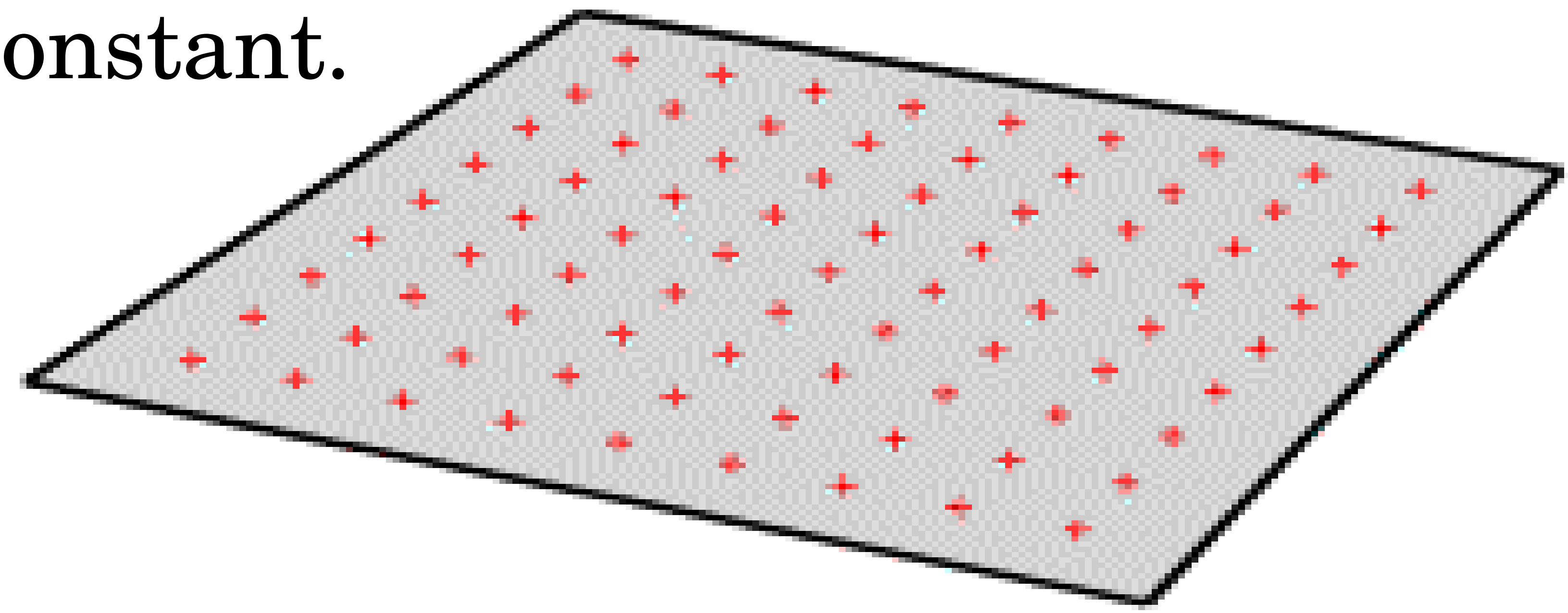
[E] Not enough info, can't tell

How large is this picture?

[A] (4'x6')
[B] 12” x 18”
[C] 50'x75'
[D] 1000'x1500'
[E] Not enough Info, can't tell


Magnitude of electric field of a plane of charge

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



Direction of field from a sphere of charge

Because of spherical symettry, the field must be radial (like a point charge)

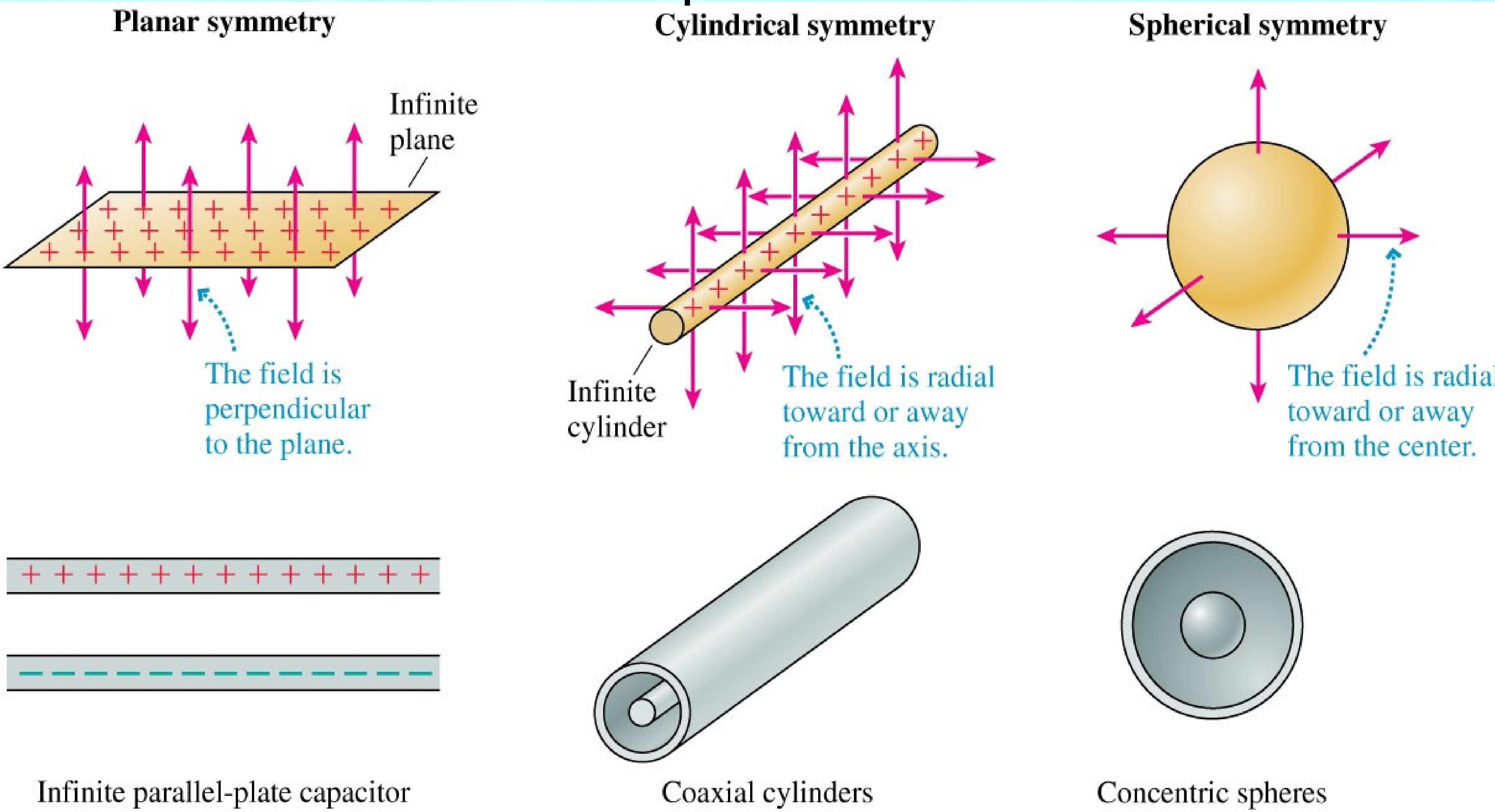
$$\vec{E} = \frac{\sigma}{2\epsilon_0}\hat{j}$$

$$\vec{E} = \frac{\lambda}{2\pi r \epsilon_0}\hat{r}$$

$$\vec{E} = 2\frac{k}{r}\hat{r}$$

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

$$\vec{E} = k\frac{Q}{r^2}\hat{r}$$



Field near a “large” vertical uniform sheet of charge

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Problem 26-39

- The electric field 5.0 cm from a very long charged wire is 2000 N/C (toward the wire). What is the charge on 1.0 cm of the wire?

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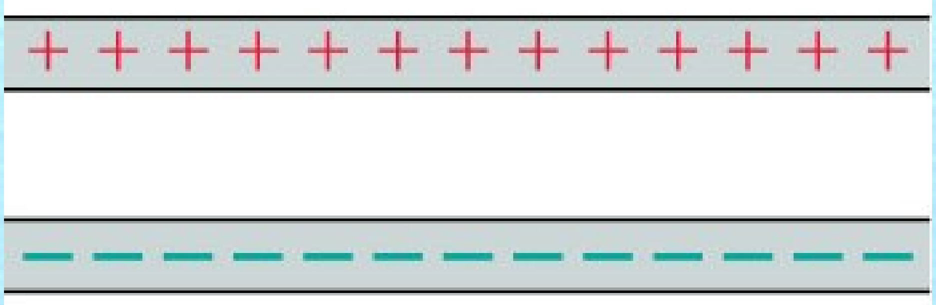
Capacitor

A capacitor is made with 2 m x 2 m square plates 2 cm apart. The plates have charges of + and – 10 uC respectively. What is the field inside the capacitor (and outside).



Infinite parallel-plate capacitor

Capacitor

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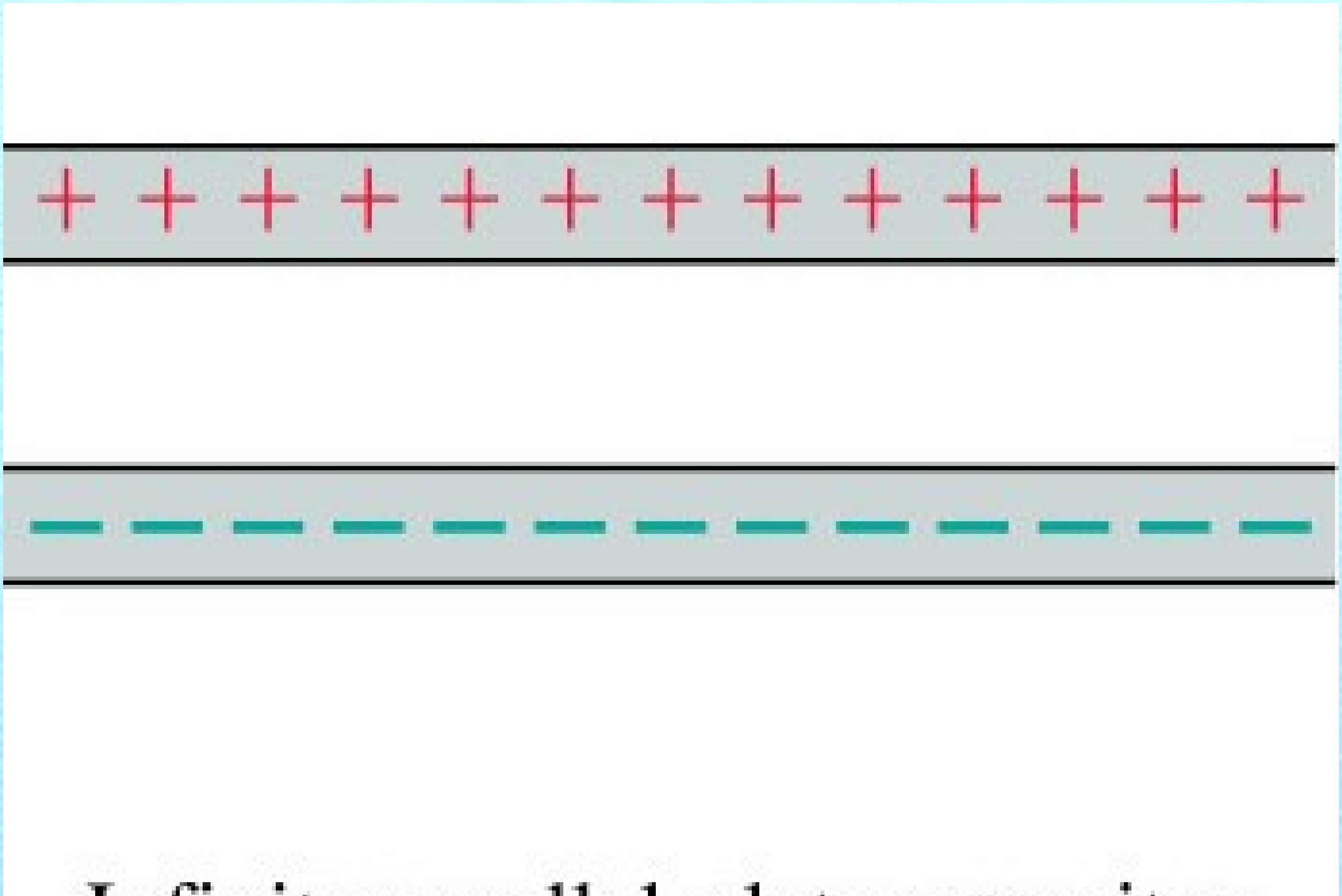


Capacitor

A capacitor is made with 2 m x 2 m square plates 2 cm apart. The plates have charges of + and – 10 uC respectively. What is the field inside the capacitor (and outside).

Clicker

You are 1 cm away from a 10 meter long charged wire, and the electric field has magnitude 27 N/C. What is the field if you go 3 cm away?

[A] 27 N/C

[B] 13.5 N/C

[C] 9 N/C

[D] 3 N/C

$$\vec{E}_{PLANE} = \frac{\sigma}{2\epsilon_0}\hat{i} \qquad \vec{E}_{LINE} = \frac{\lambda}{2\pi r \epsilon_0}\hat{r} \qquad \vec{E}_{SPHERE} = \frac{Q}{4\pi r^2 \epsilon_0}\hat{r}$$

Clicker

You are 1 cm away from a 10 m square charged To 2 nCoul. What is the electric field?

$$\vec{E}_{PLANE} = \frac{\sigma}{2\epsilon_0}\hat{i}$$

$$\vec{E}_{SPHERE} = k\frac{Q}{r^2}\hat{r} = \frac{Q}{4\pi r^2 \epsilon_0}\hat{r}$$

[A] 1.13 V/m

[B] 2.26 V/m

[C] 113 N/C

[D] $2\times10^{-9}\,V/m$

[E] $2\times10^{-11}\,V/m$

Clicker

You are 100 m away from a 10 m square charged to 2 nCoul. What is the electric field?

[A] 1.13 V/m

[B] $1.13\times10^{-2}\,V/m$

[C] 113 V/m

[D] $18\times10^{-2}\,V/m$

[E] $18\times10^{-4}\,V/m$

$$\vec{E}_{PLANE}=\frac{\sigma}{2\epsilon_0}\hat{i}$$

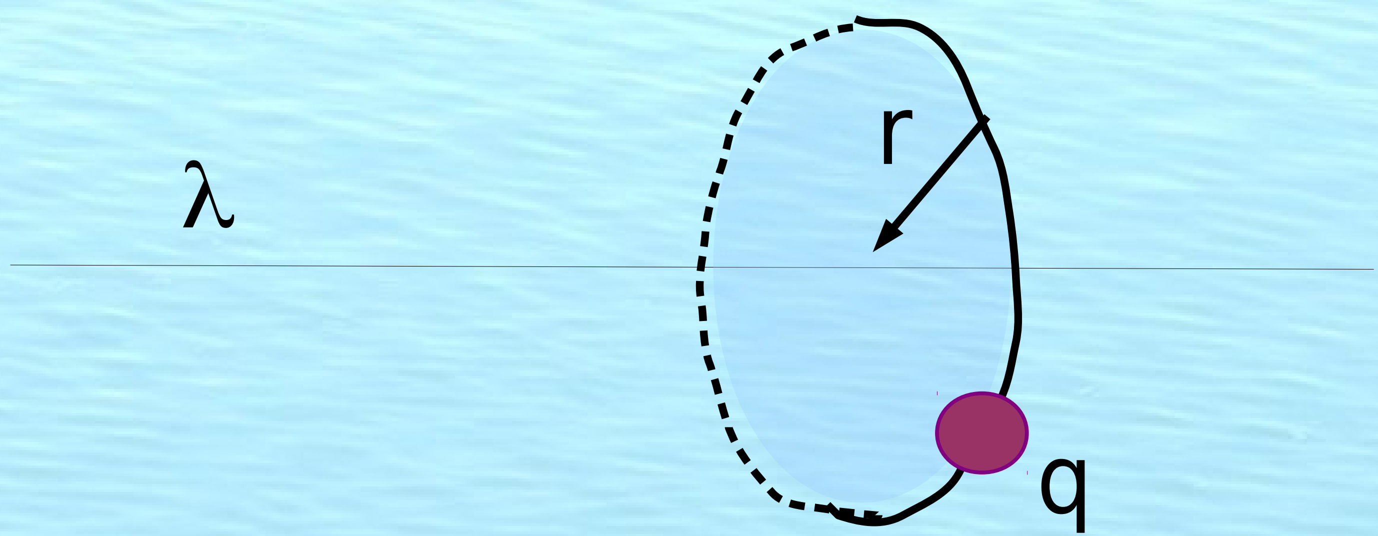
$$\vec{E}_{SPHERE}=k\frac{Q}{r^2}\hat{r}=\frac{Q}{4\pi r^2\epsilon_0}\hat{r}¿$$

Problem

What is line charge density on a long wire if a 10 microgram particle carrying 3 nC orbits at 300 m/s?

$$\overrightarrow{E_{wire}} = 2k\frac{\lambda}{r}\hat{r}$$

$$\lambda = \frac{Q}{L}$$



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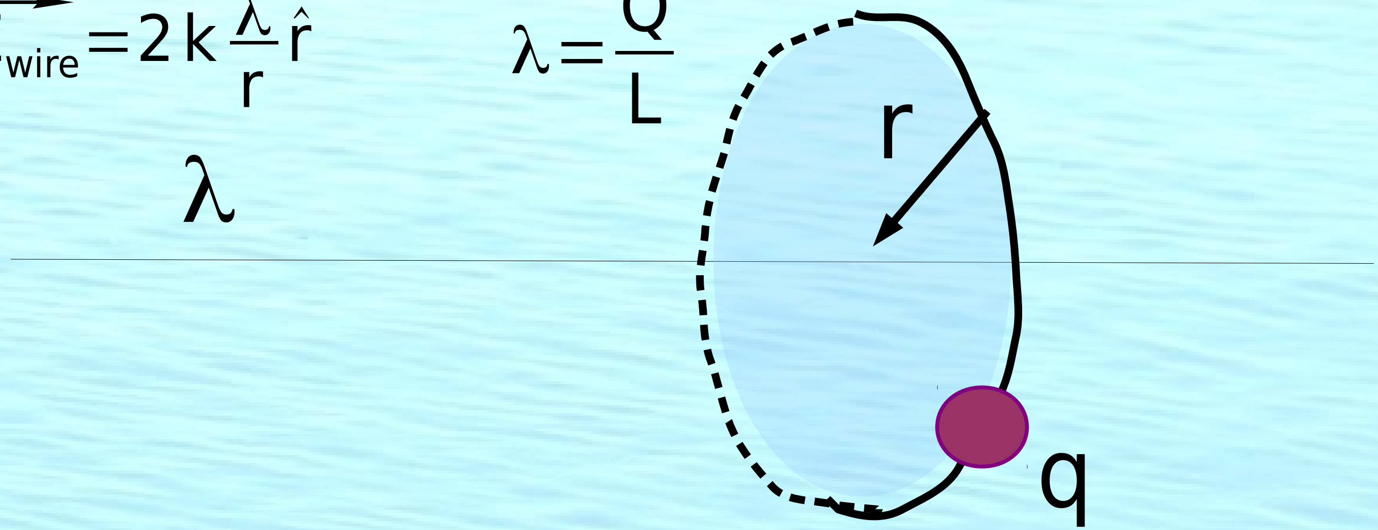
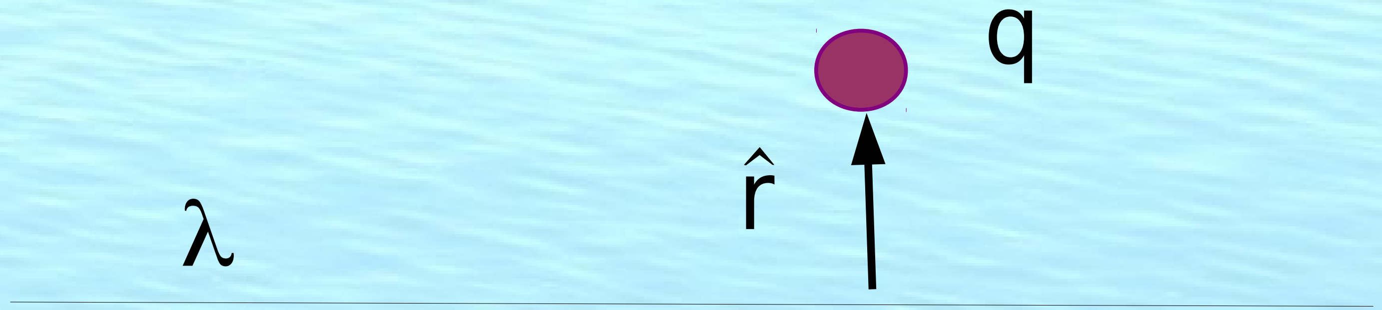


Electric field of a charged wire – Derivation

$$\overrightarrow{E_{wire}} = 2k\frac{\lambda}{r}\hat{r}$$

$$\lambda = \frac{Q}{L}$$

$$\vec{E} = \int k\frac{dq}{r^2}\hat{r}$$



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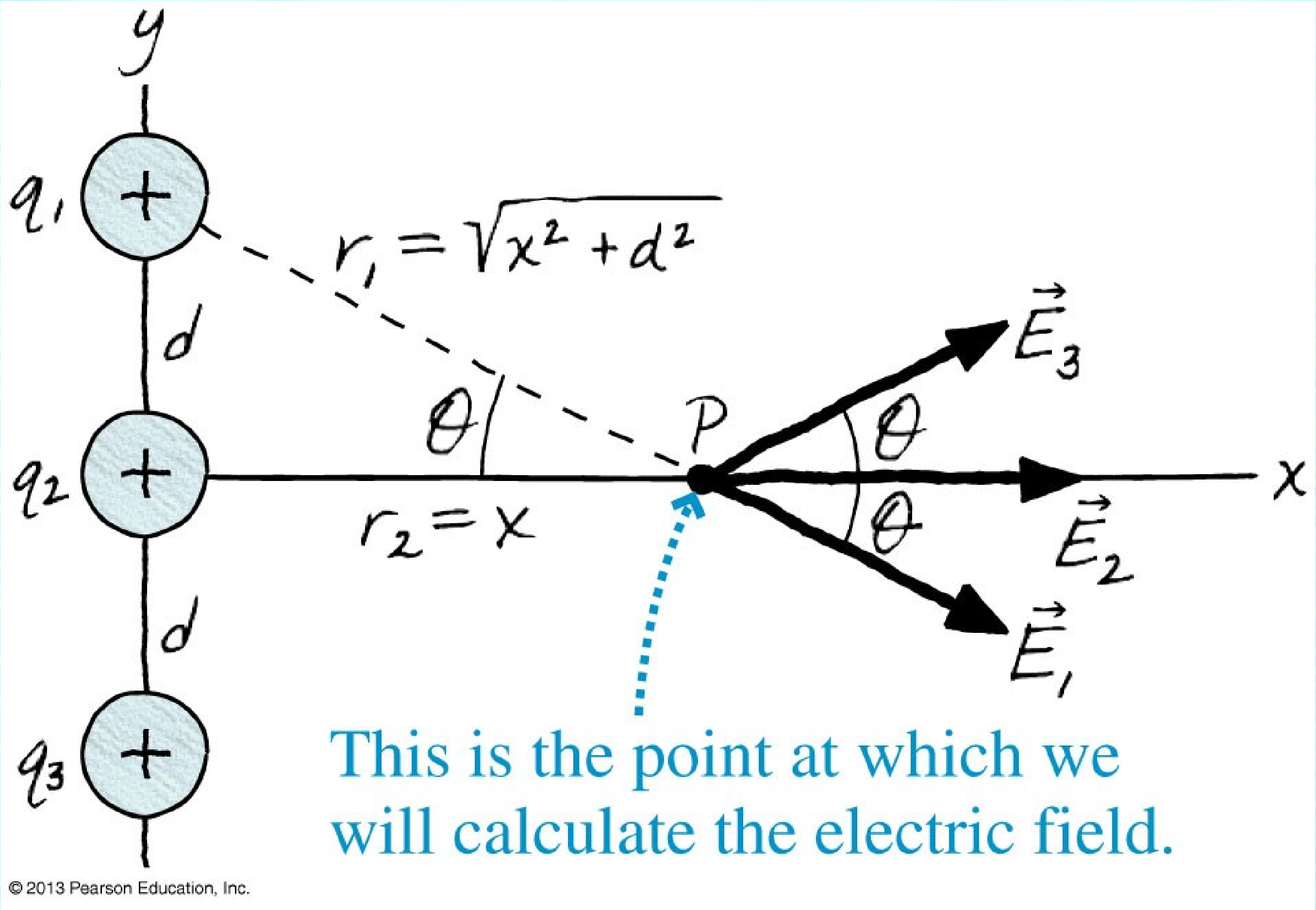
Electric field of three charges



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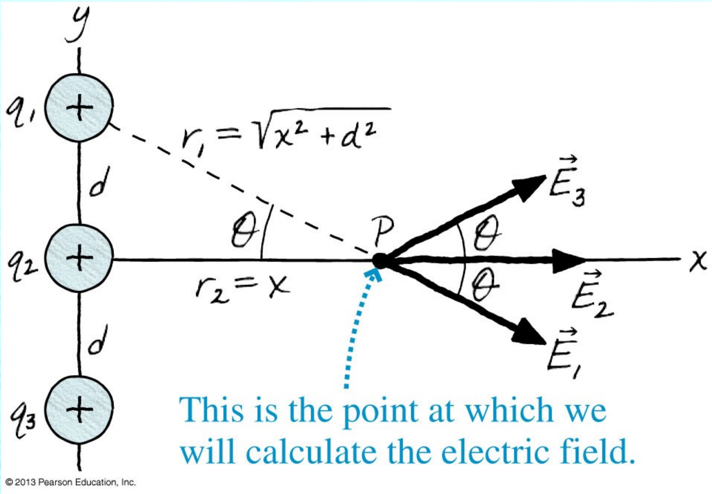
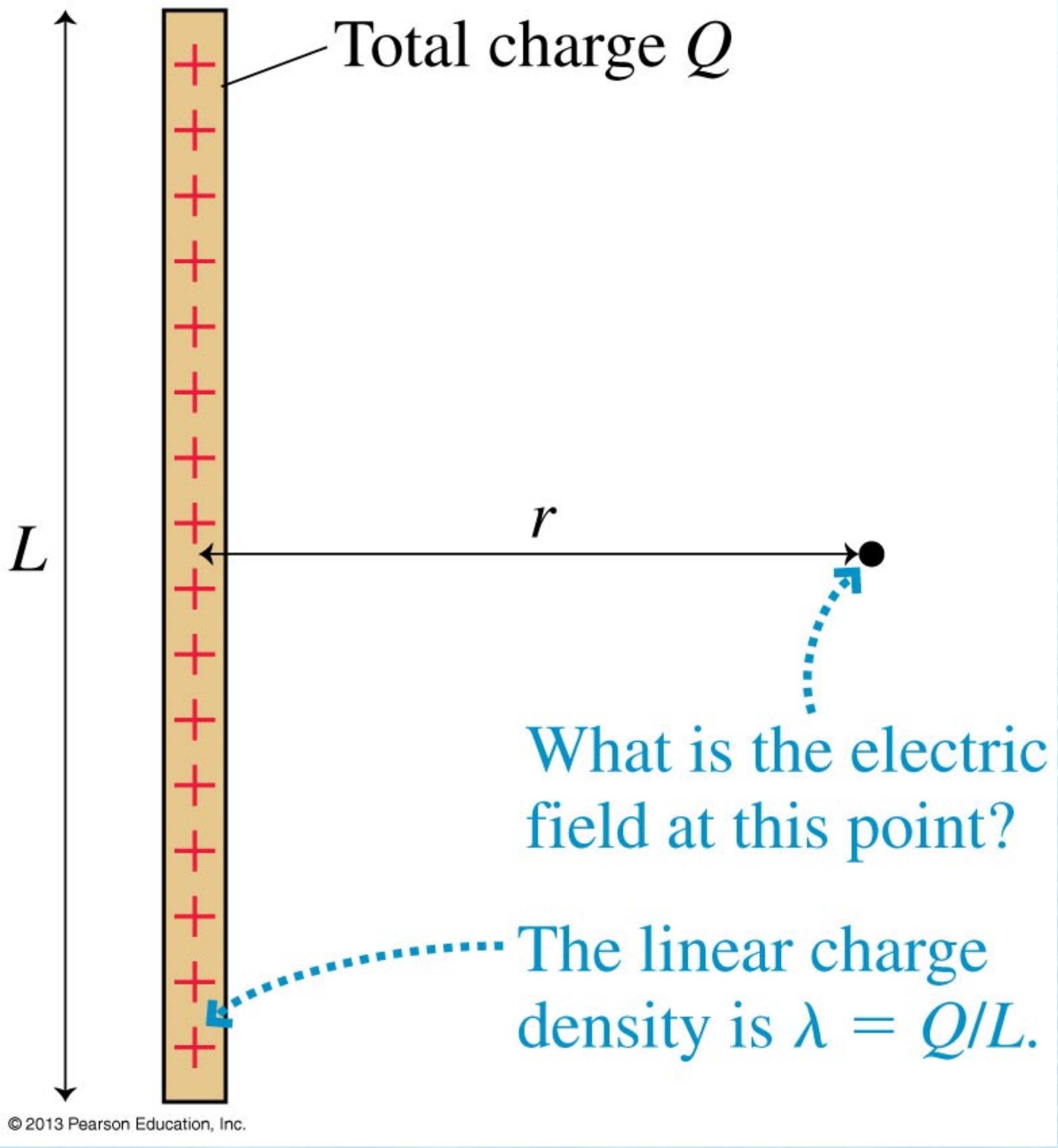
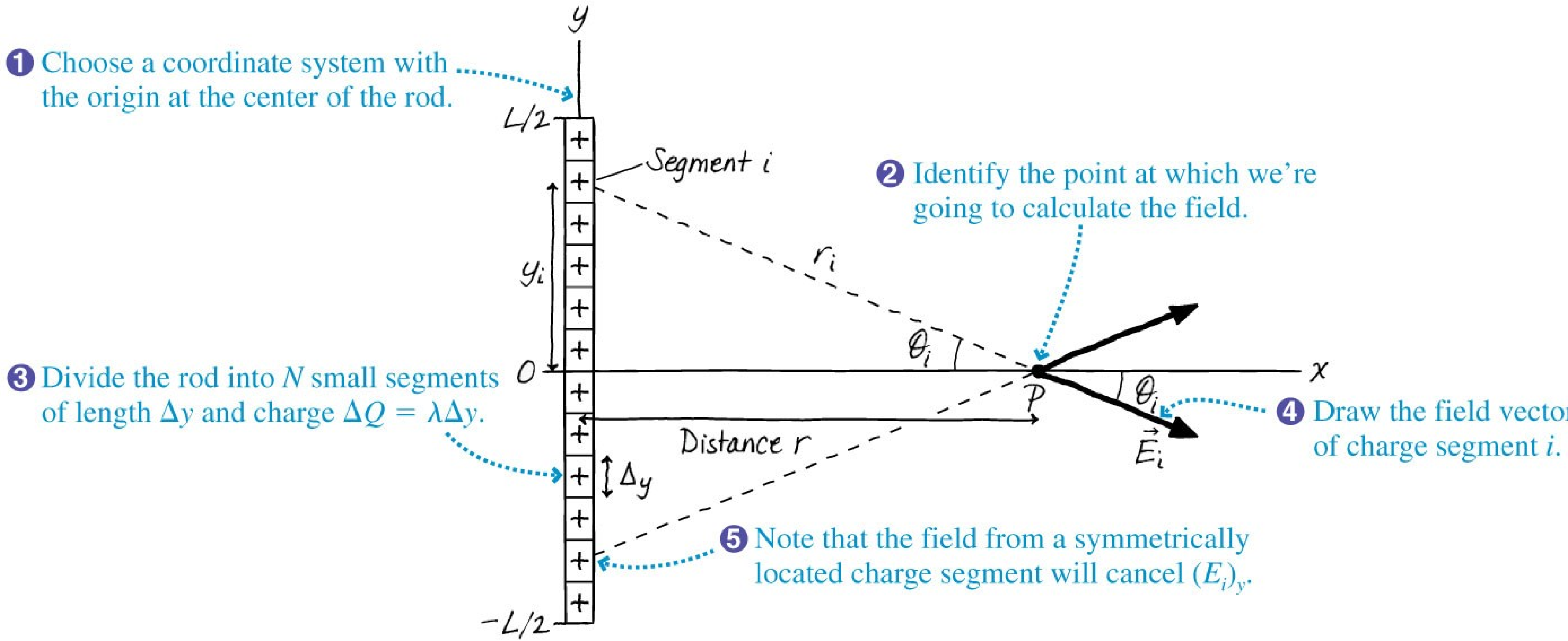


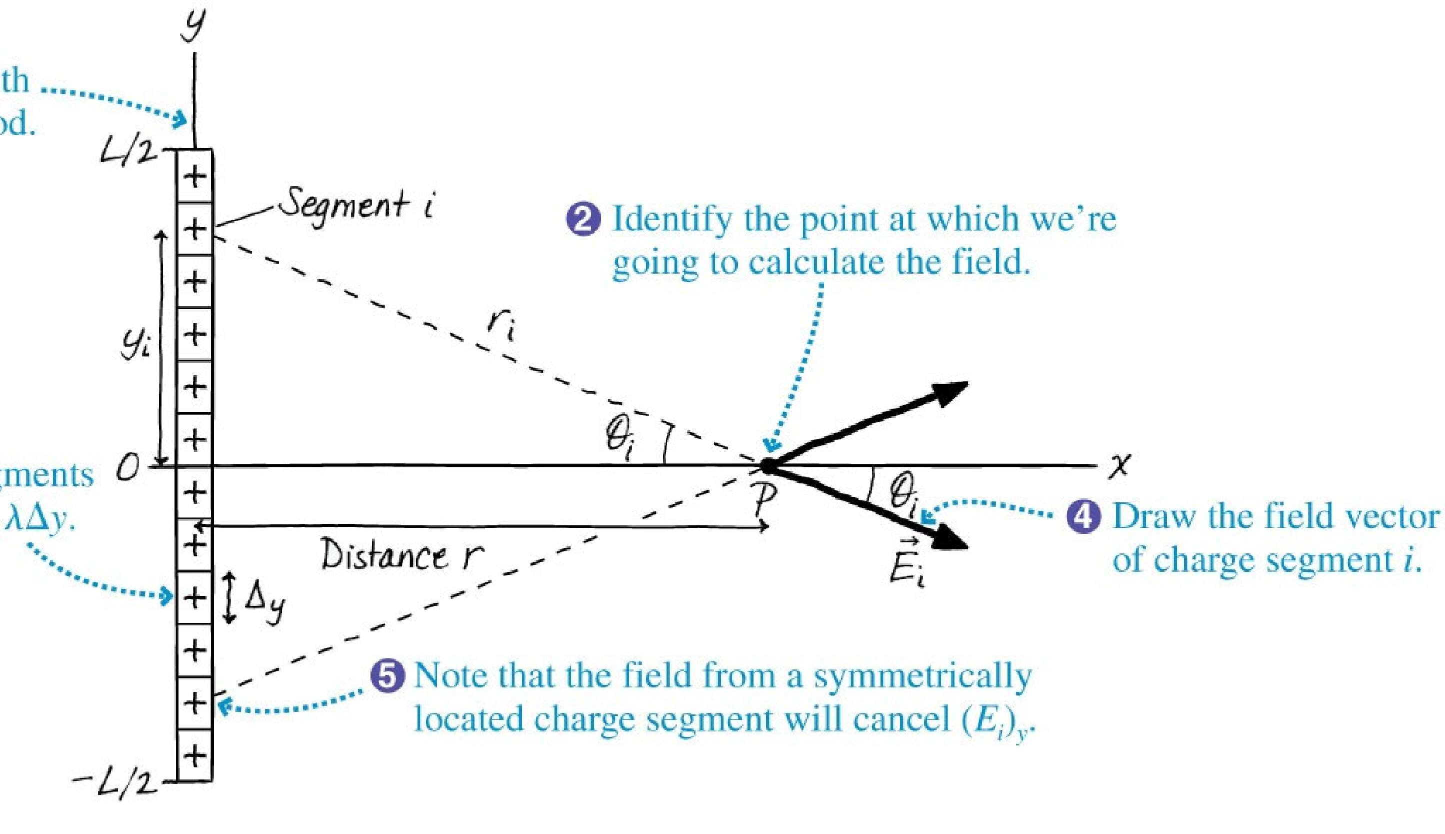
Figure 26.11

Electric field of charged wire





1 Choose a coordinate system with the origin at the center of the rod.
2 Identify the point at which we're going to calculate the field.
3 Divide the rod into N small segments of length Δy and charge ΔQ = λΔy.
4 Draw the field vector of charge segment i.
5 Note that the field from a symmetrically located charge segment will cancel $(E_i)_y$.
y
x
L/2
−L/2
0
Segment i
y_i
r_i
θ_i
P
Distance r
Δy
$\vec{E}_i$



th
od.
gments
λΔy.
y
L/2
Segment i
y_i
r_i
θ_i
0
P
x
Distance r
Δy
θ_i
$\vec{E}_i$
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❷ Identify the point at which we're going to calculate the field.
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Electric field of a charged wire

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Potential Energy (Unit: Joule)

The energy an object gains as it moves from point A to point B for a given applied force. An object with high potential energy will spontaneously convert it to kinetic energy if released.

Potential energy is INDEPENDENT of path from A to B.

Electric Potential (Unit: Volt)

The energy a one Coulomb charge would gain as it moves from point A to B in an electric field. A positive charge at high voltage will spontaneously convert it to kinetic energy if released.

An "equipotential line" is one at which the potential is the same everywhere (and at which identical charges would have identical potential energies). It takes NO WORK to move a charge from one part of an equipotential line to another.

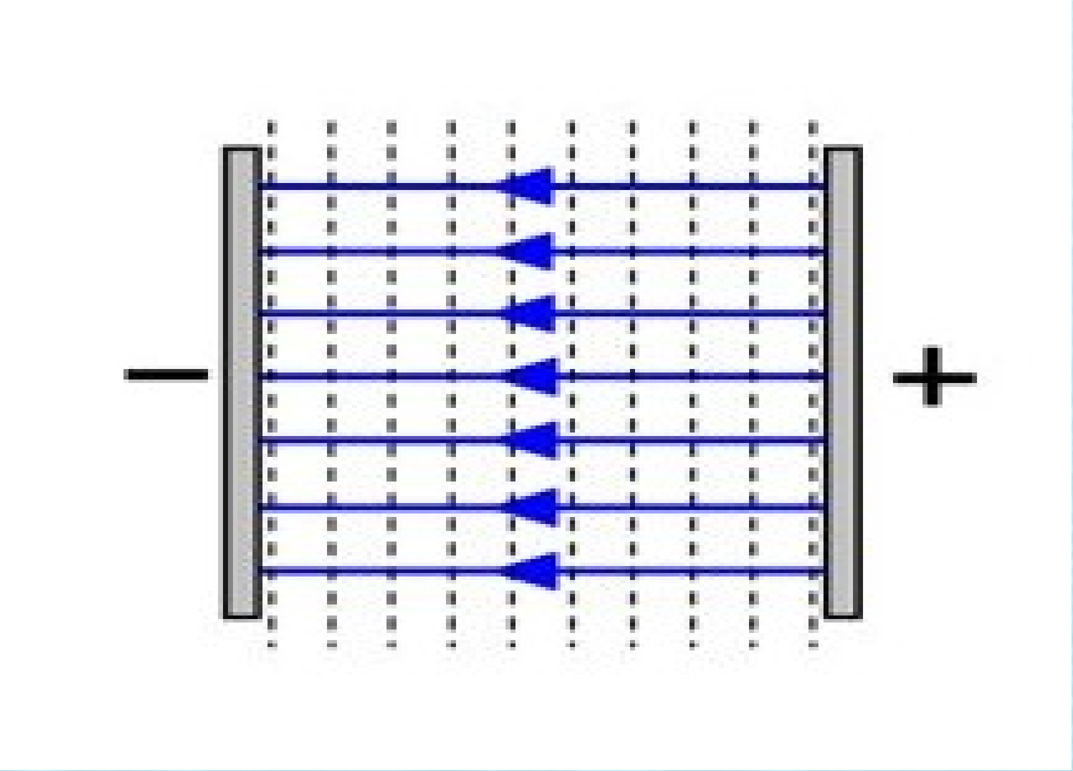
Parallel Plates

Equipotentials are equally spaced lines.

$$V = \frac{\sigma}{\epsilon_0} x$$

Electric field is constant in magnitude.

$$\vec{E} = \frac{\sigma}{\epsilon_0} \hat{n}$$

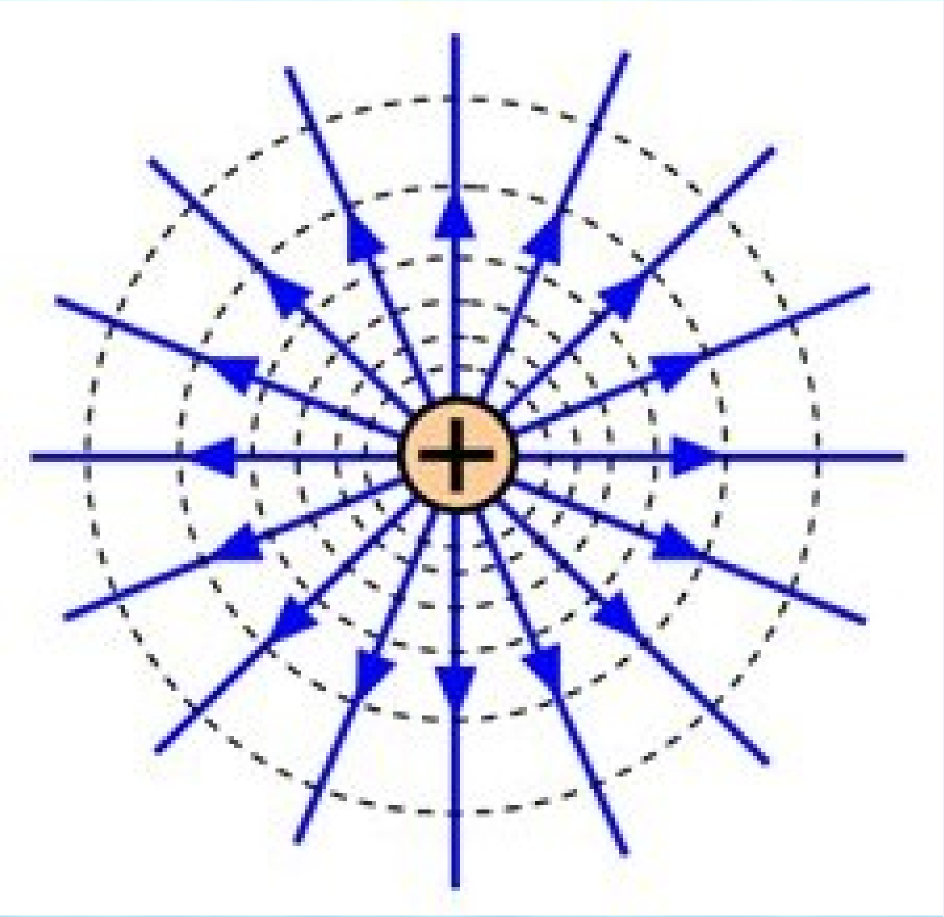


Coaxial Cylinders

Equipotentials are circles and closer together near center electrode

$$V = \frac{\lambda}{2\pi\epsilon_0}\ln\left(\frac{r}{r_1}\right)$$

Electric field is radial
And decreases with distance

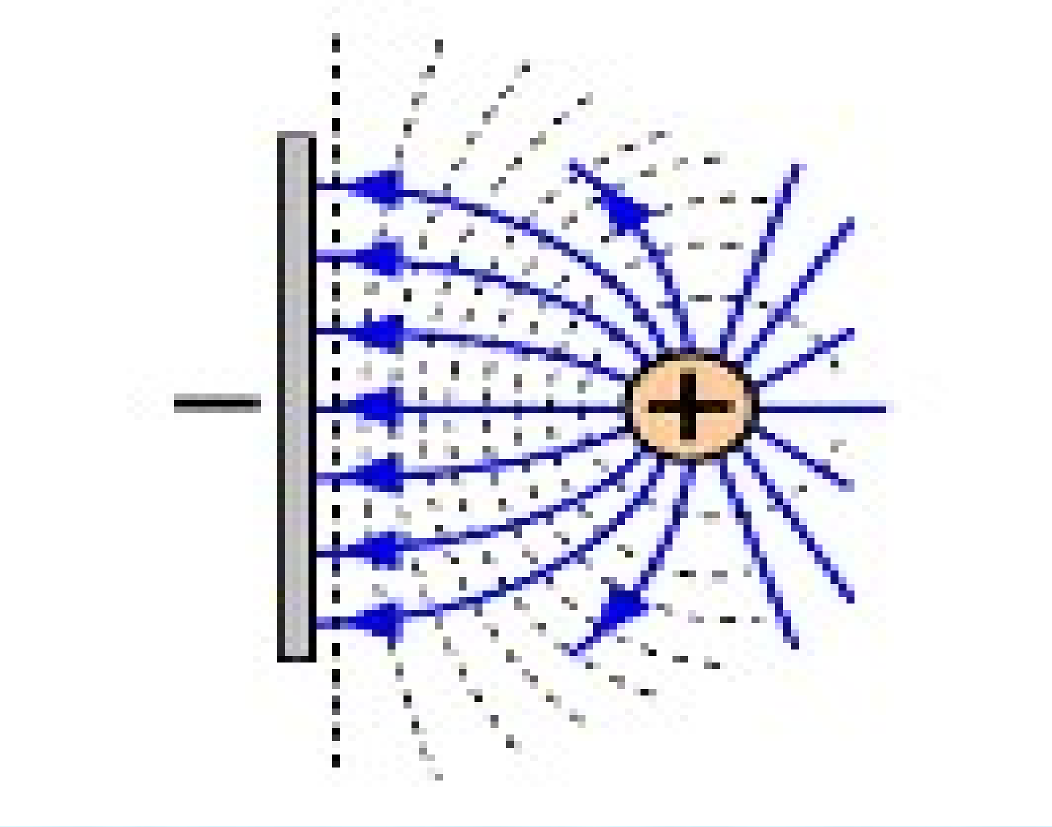


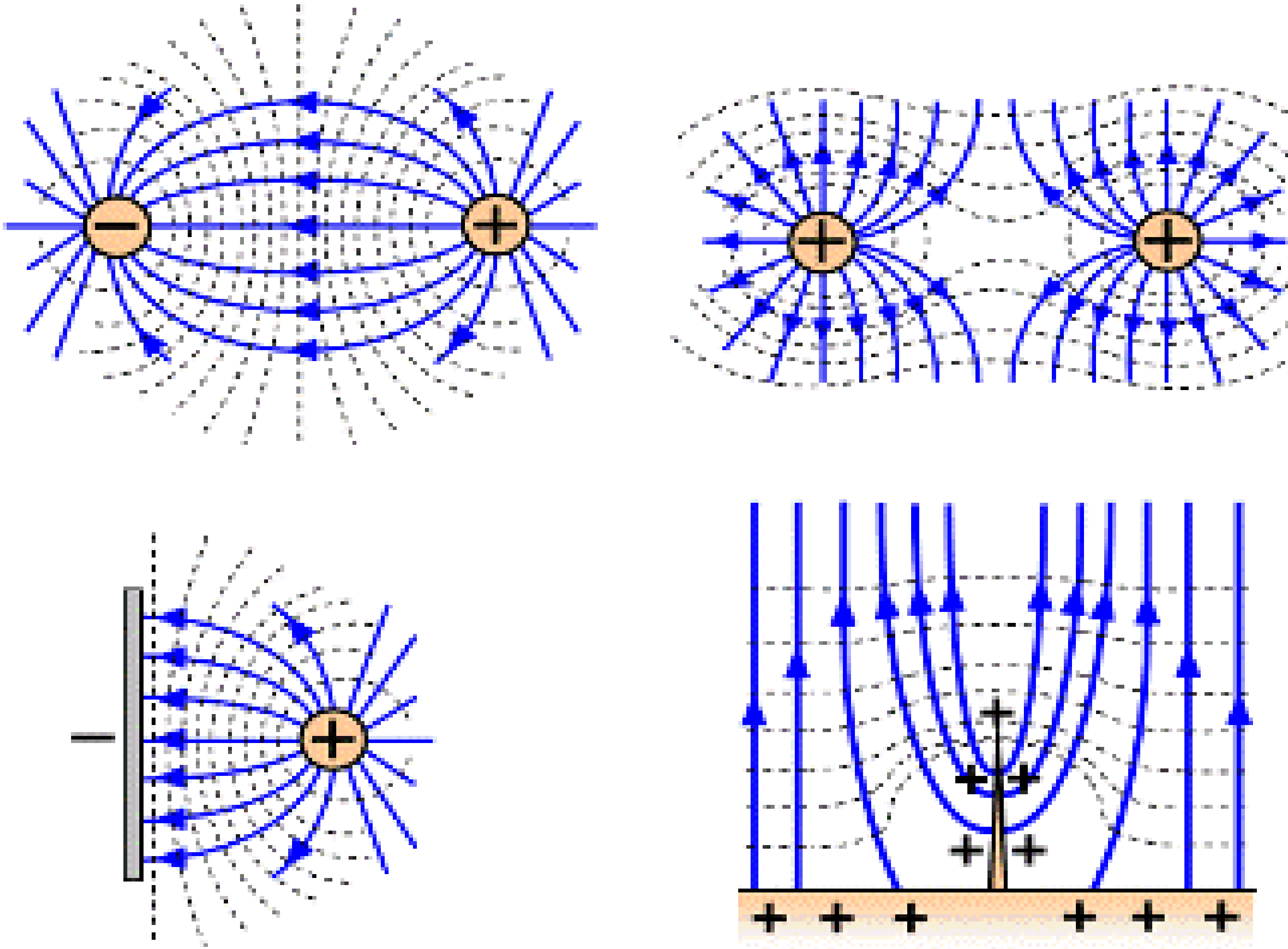
$$\vec{E} = \frac{\lambda}{2\pi r\epsilon_0}\hat{r}$$

Cylinder over plane

Near plane, equipotentials are equally spaced.

Near cylinder, equipotentials look more like Coax.





(resourcefulphysics.org)

Field Lines

Originate at positive charges.
Terminate at negative.

Closer spacing means larger fields.

Never cross.

Are at right angles to conductors.

Equipotentials

The voltage is the same everywhere on an equipotential

Closer spacing means larger fields.

Never cross.

Are at right angles to field lines. (Are parallel to conductors)