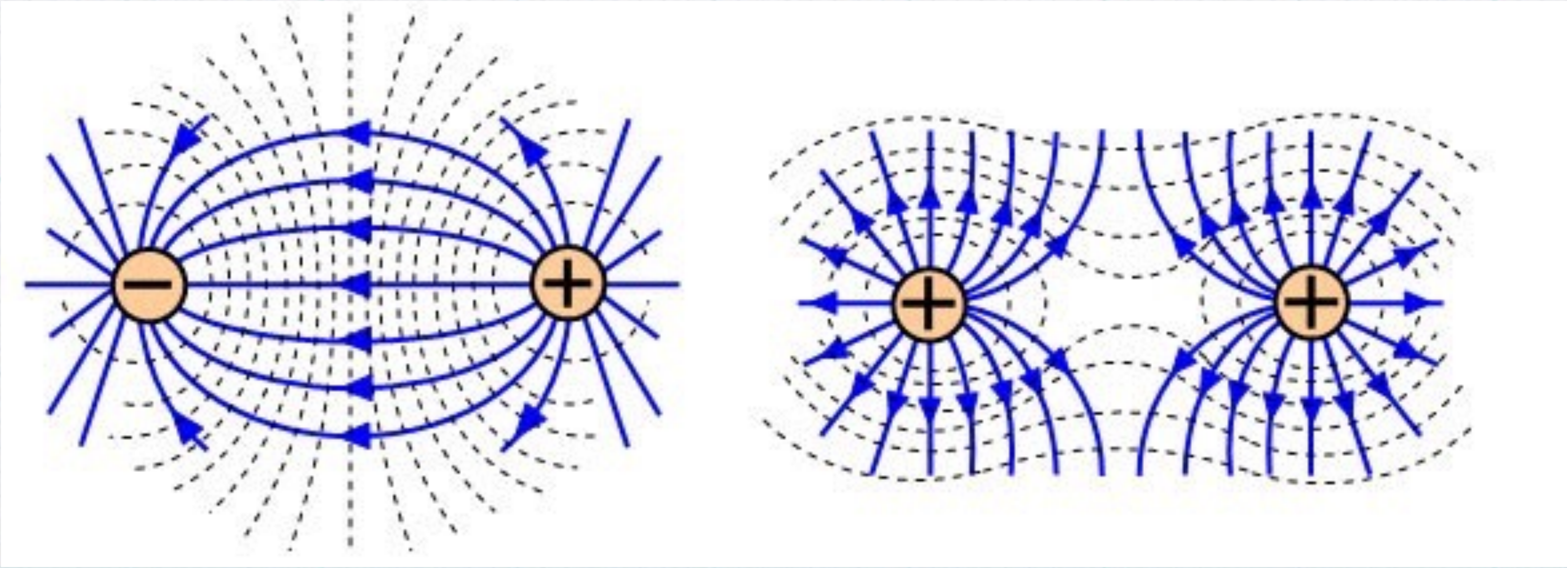
Electric Fields

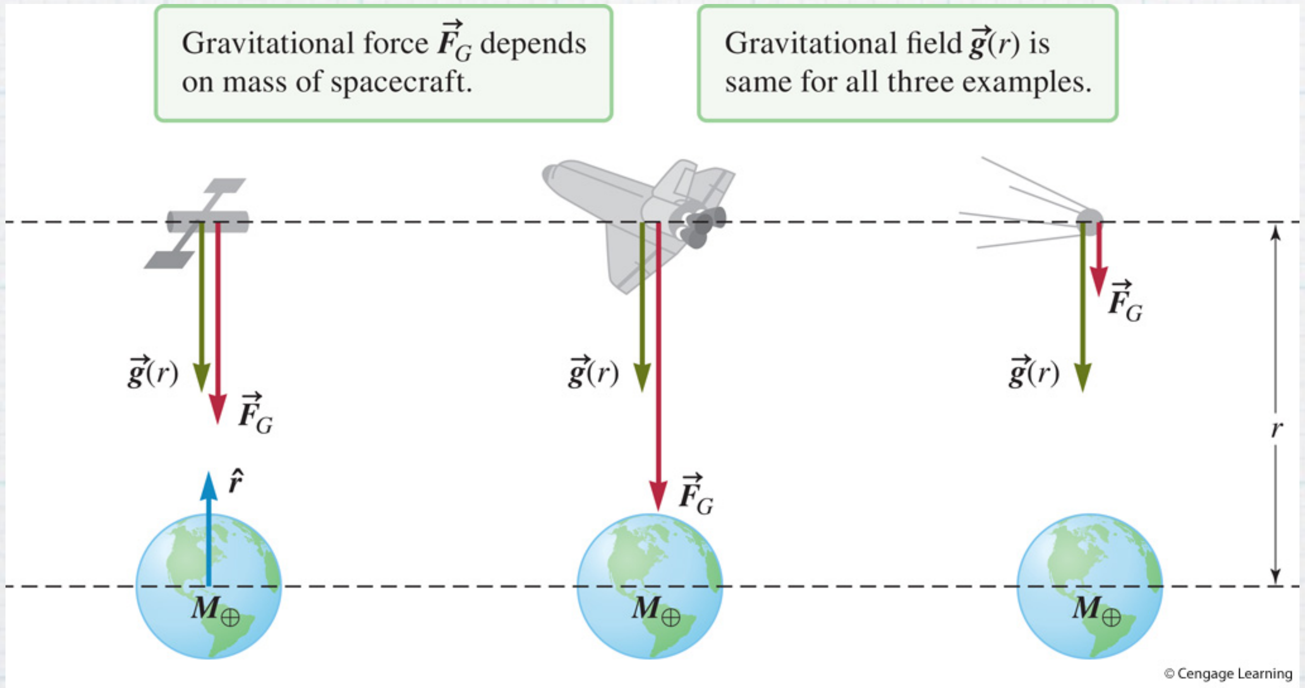
Or, it's going to get harder

Fields



Fields

* Represent an influence waiting to happen
* Fields are produced by potential sources of interactions due to influences
* There can be vector fields and scalar fields
* Example

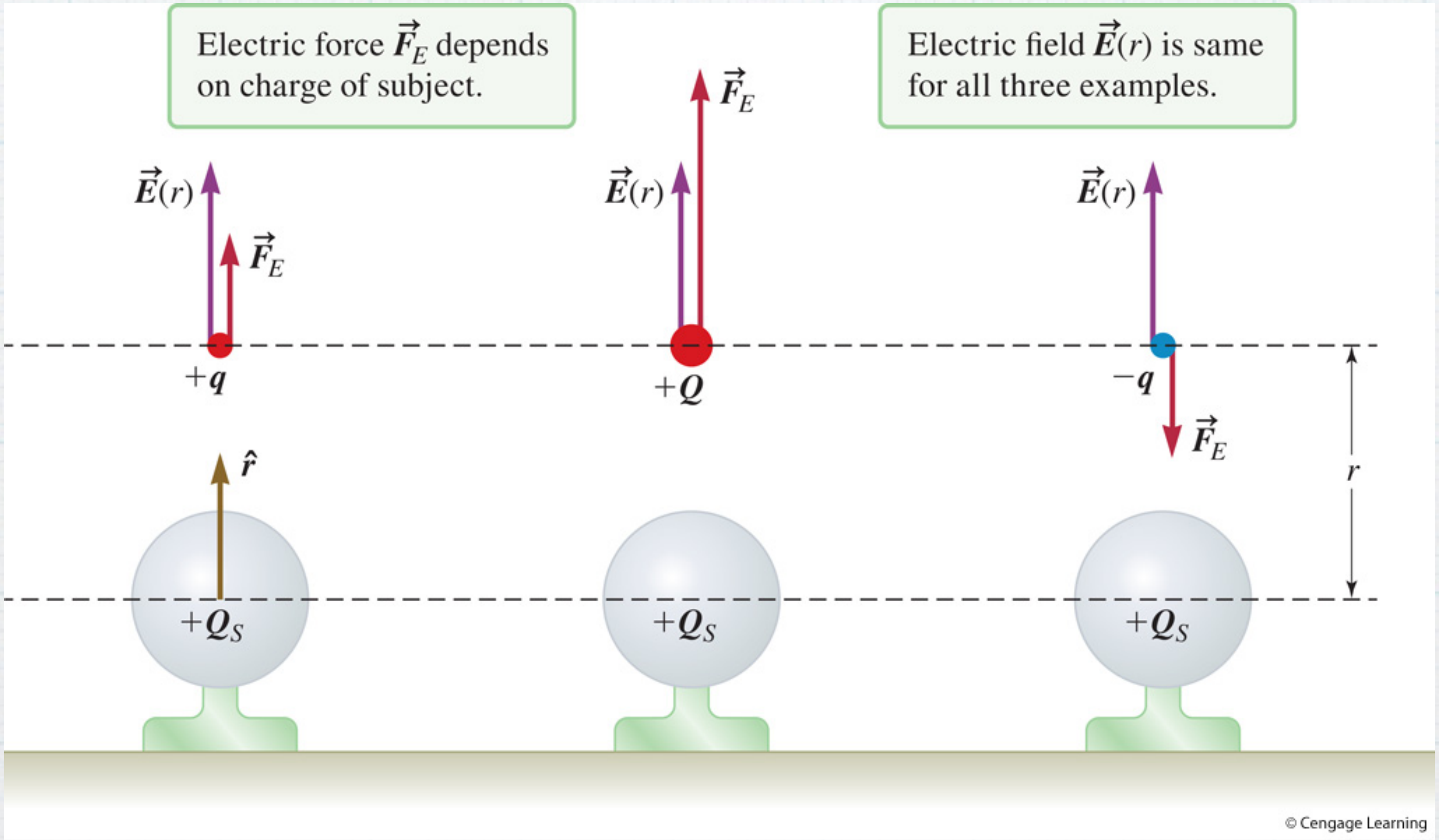


$$\vec{F}_g = \frac{-Gmm_1}{r^2}\hat{r} = m_1\vec{g} \rightarrow \frac{\vec{F}_g}{m_1} = \vec{g}$$

Think of the electric field

* As produced by "source" charges, an influence waiting to happen
* They add vectorially. You calculate the influence and then place a charge in this influence to determine the force on a test particle
* The electric field is ALWAYS WRT to a positively charged test particle
* Units are N/C
* If I stick a charge with C coulombs in the field it experiences a force of N newtons

$$\vec{F}_e = \frac{kqq_1}{r^2}\hat{r} = q_1\vec{E} \rightarrow \frac{\vec{F}_e}{q_1} = \vec{E}$$



Reading Question 24.2

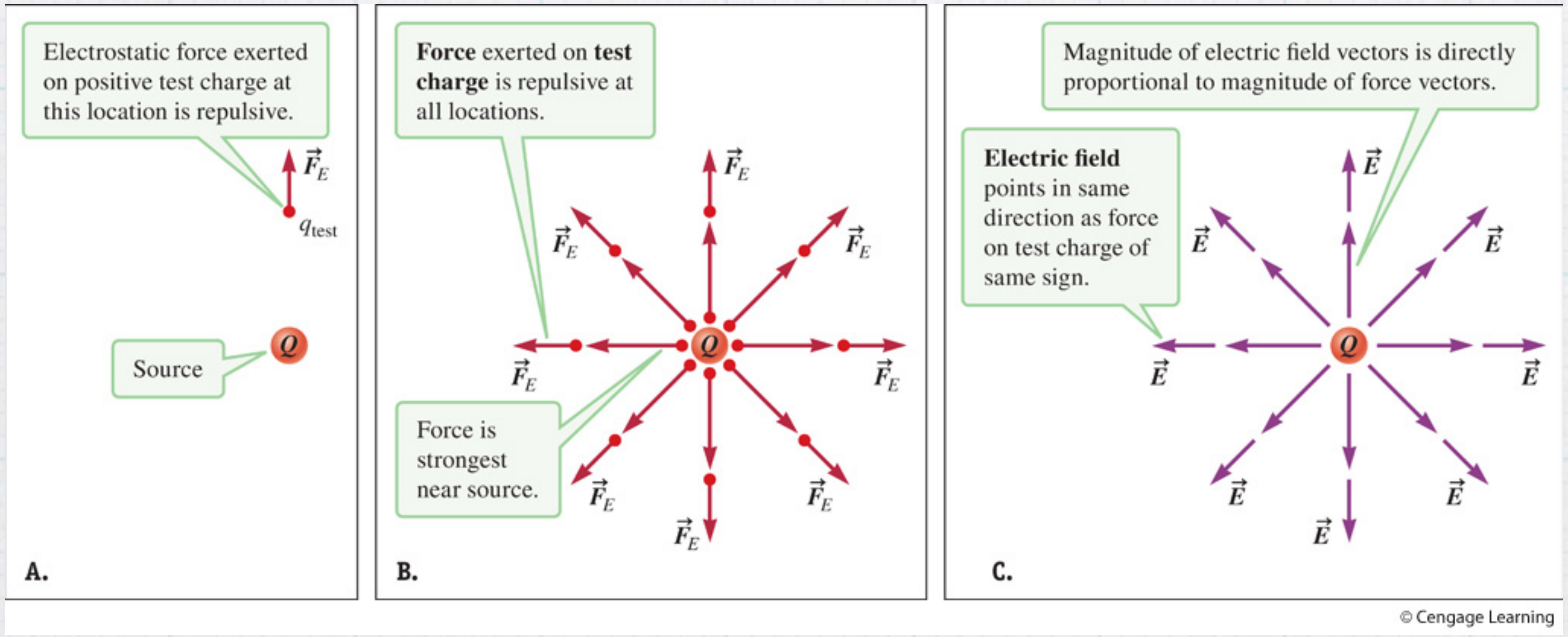
Which of the following is true for a gravitational field but not true for an electric field?

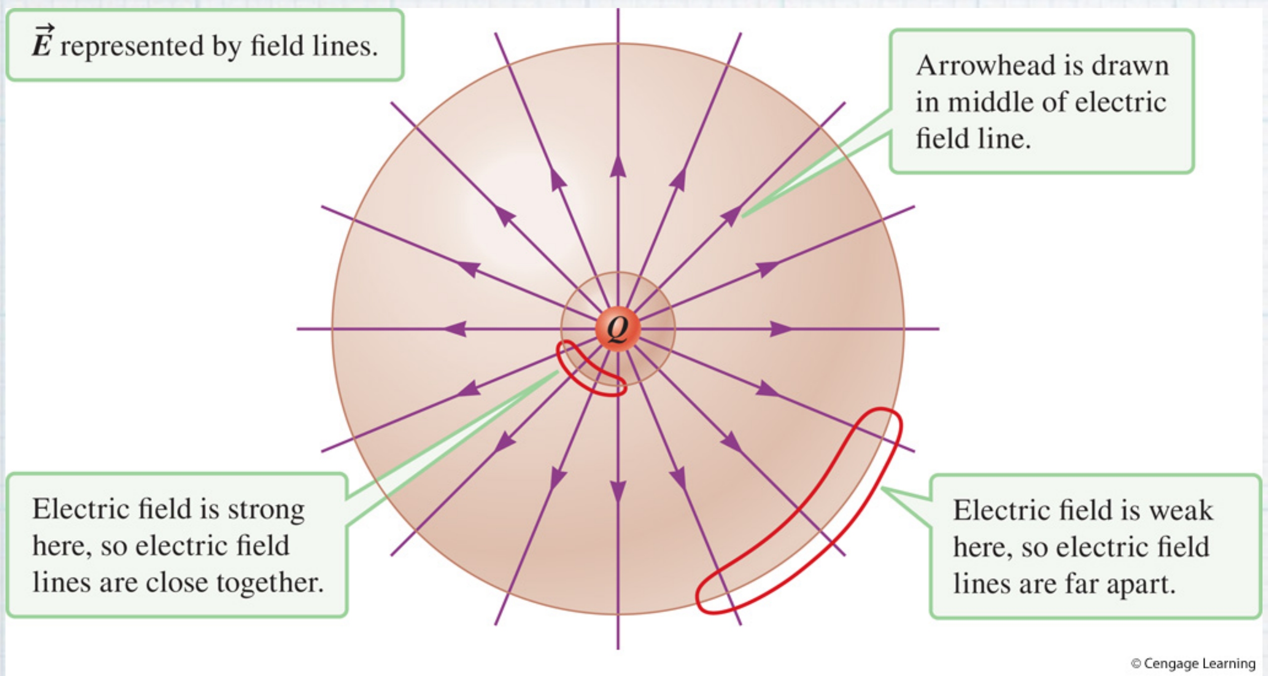
a. Magnitude of the field drops as the square of the distance from the source
b. Has a constant of proportionality
c. Is radially directed towards the source
d. Depends on only one property of the source

Electrical field of a spherical charge

$$\vec{E} = \frac{\vec{F}}{q_{test}} = k\frac{q}{r^2}\hat{r}$$

Don't forget r points towards location of electric field




$\vec{E}$ represented by field lines.
Arrowhead is drawn in middle of electric field line.
Q
Electric field is strong here, so electric field lines are close together.
Electric field is weak here, so electric field lines are far apart.
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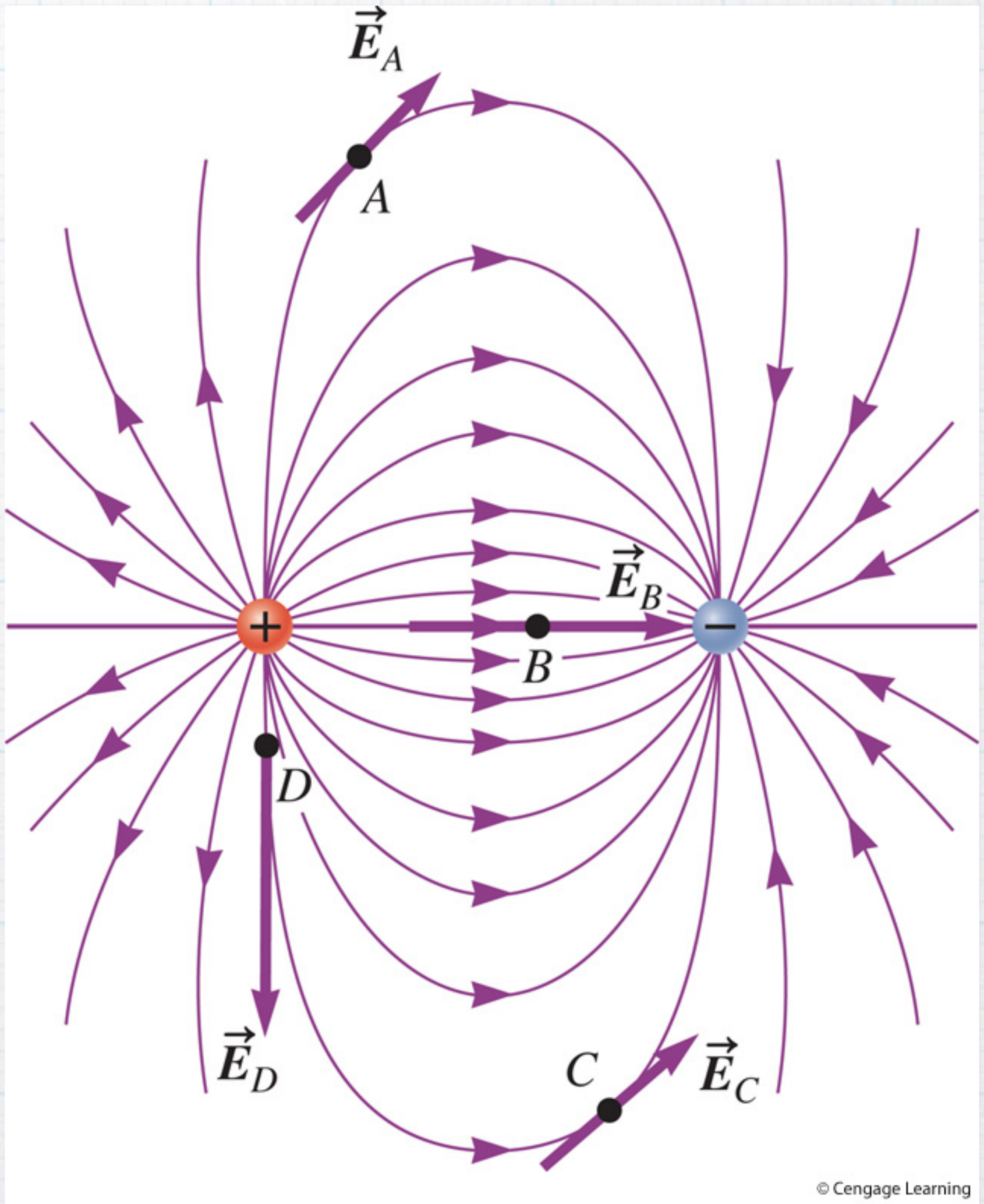
$\vec{E}_A$
A
$\vec{E}_B$
B
D
$\vec{E}_D$
C
$\vec{E}_C$
+
−
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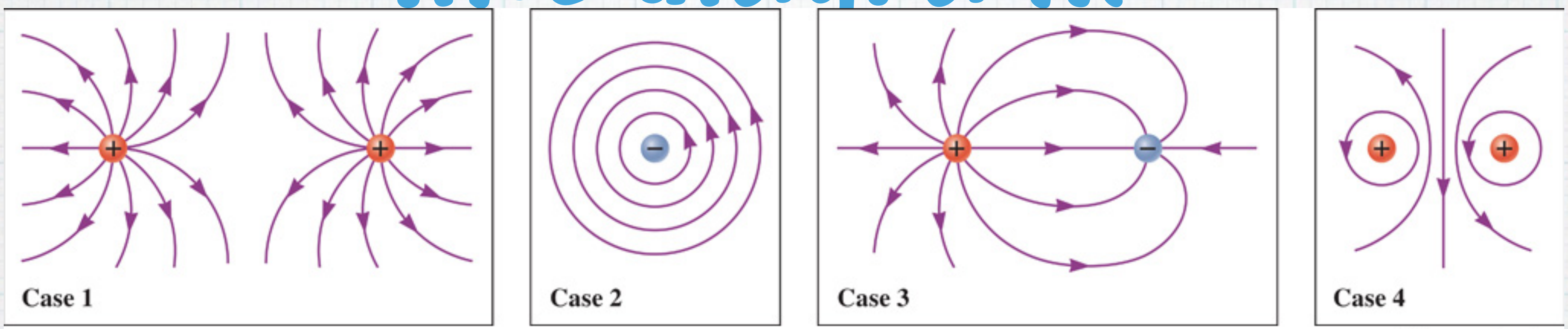
Which cannot be a field line diagram?



Reading Question 24.1

An electric field and a temperature field differ in that:

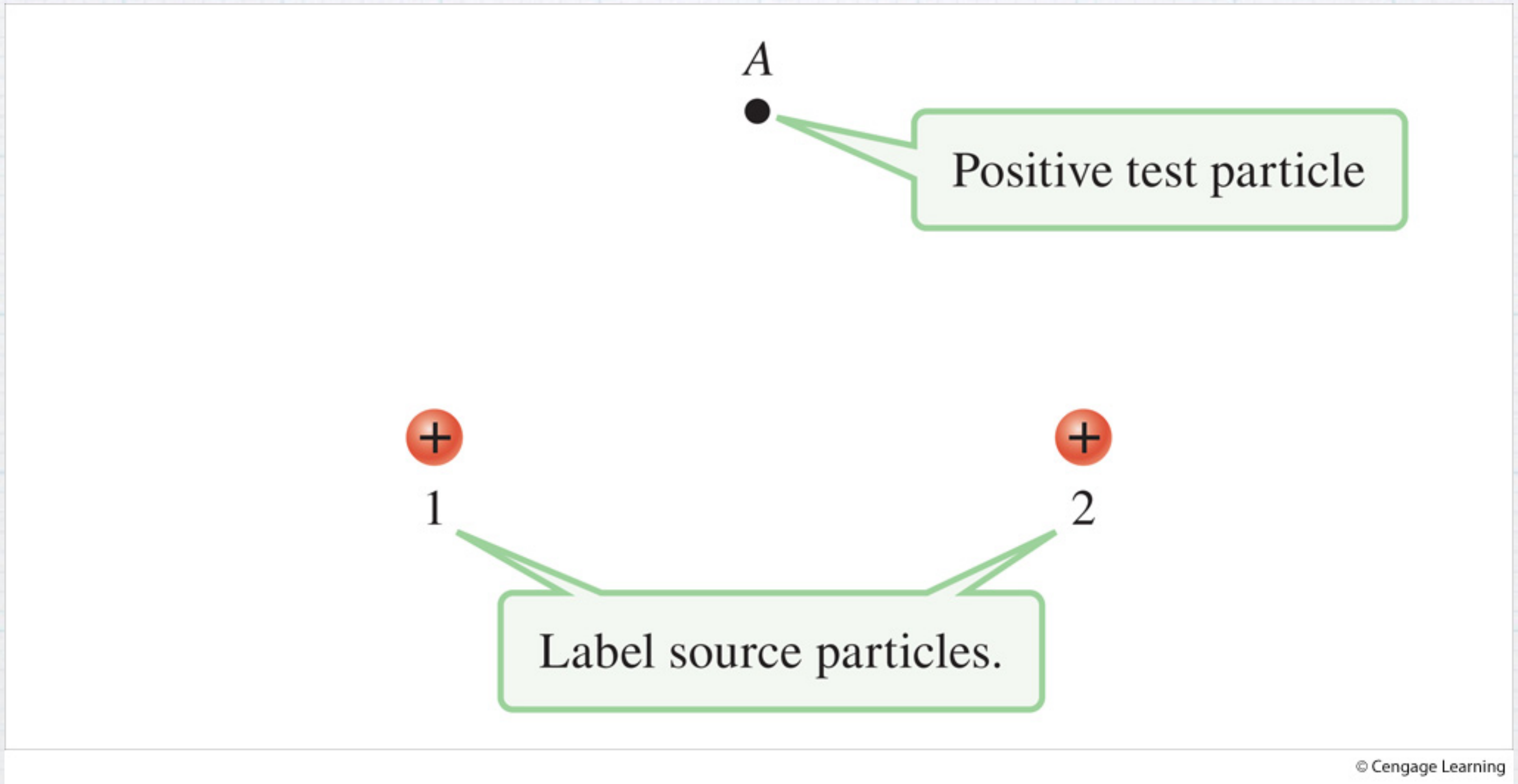
a. Only the electric field is a scalar field
b. Only the temperature depends on the properties of its source
c. Only the electric field has a directional component
d. Only the temperature is a vector field

Let's do the hydrogen atom again

What about the electric field due to a collection of charges?

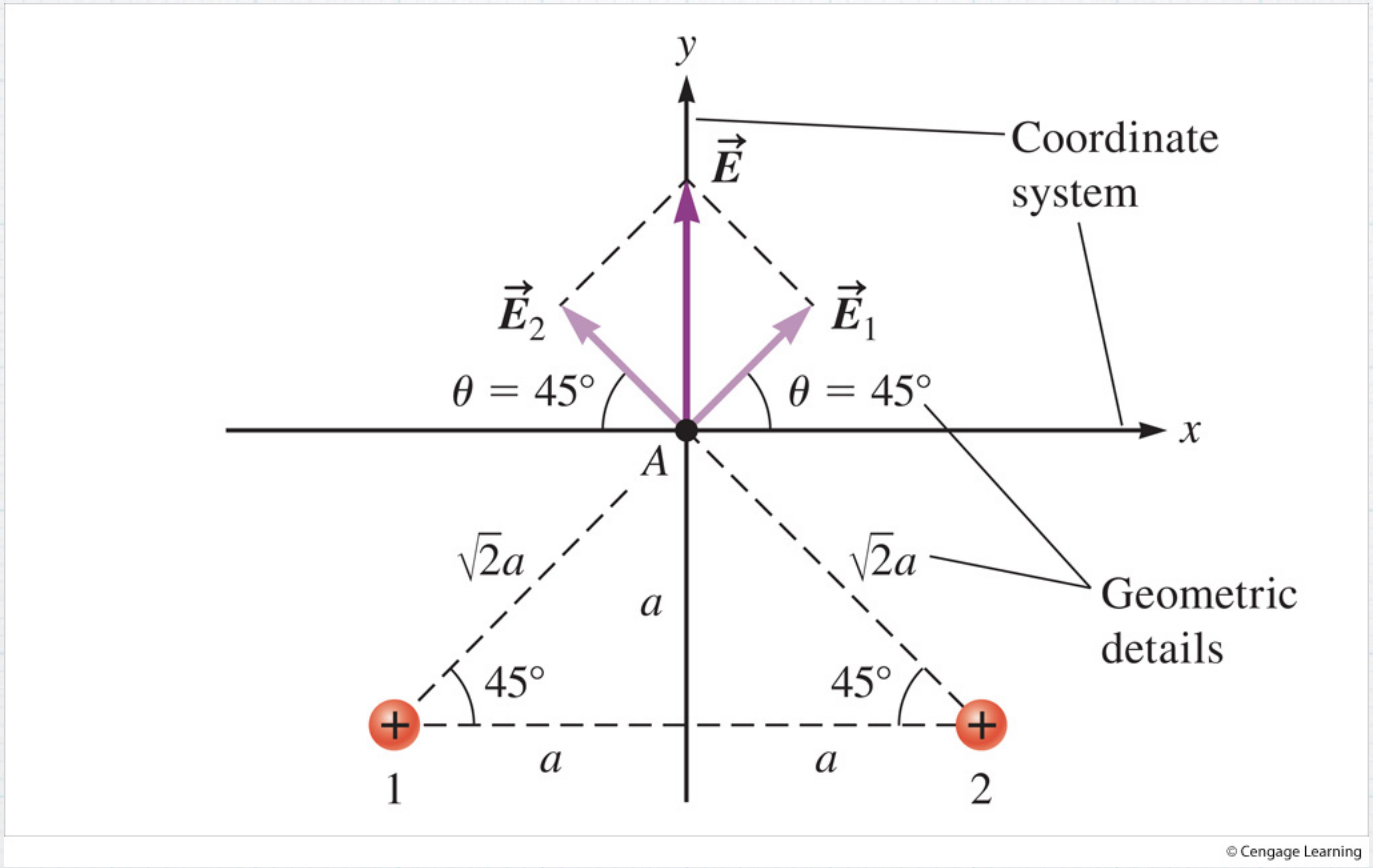
* Same as for forces but easier
* Calculate the magnitude of the electric field due to each particle
* Separate into vector components
* Add them up
* If you want the force a particle placed in that location would experience simply multiply the electric field by the particle's charge

Example 1



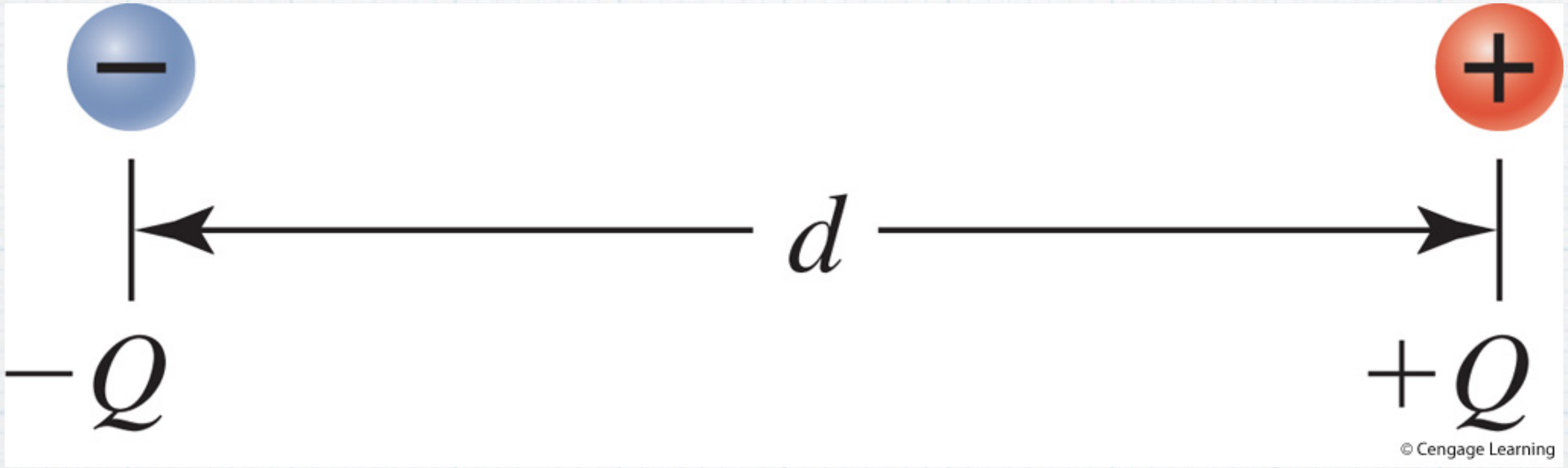
We'll do this the stupid way

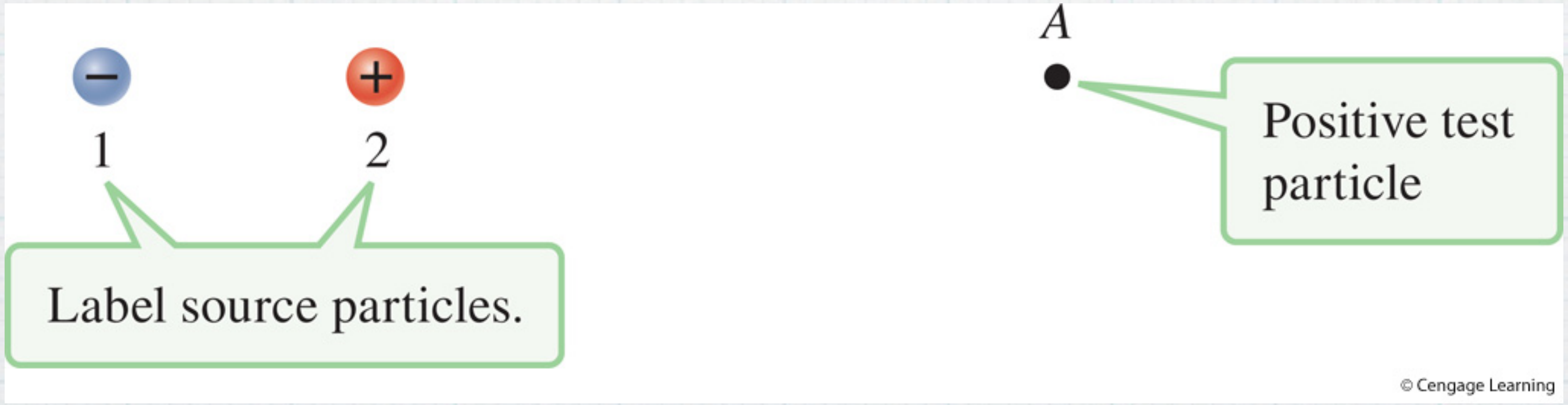
Then the smart way

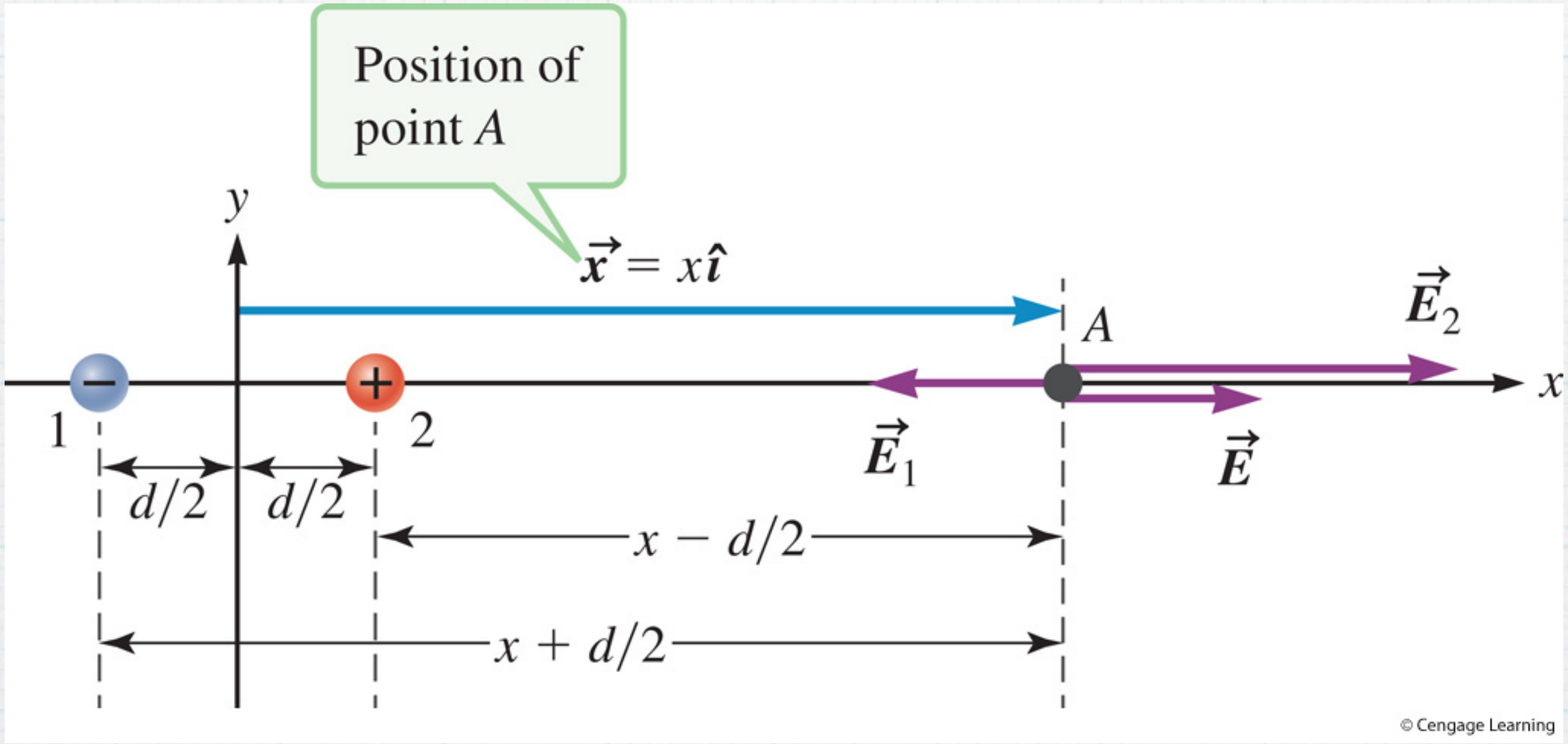


What if 1 went to 2e or -2e?

Example2, dipole







Position of point A
$\vec{x} = x\hat{\imath}$
y
x
A
$\vec{E}_2$
$\vec{E}_1$
$\vec{E}$
1
2
d/2
d/2
x − d/2
x + d/2
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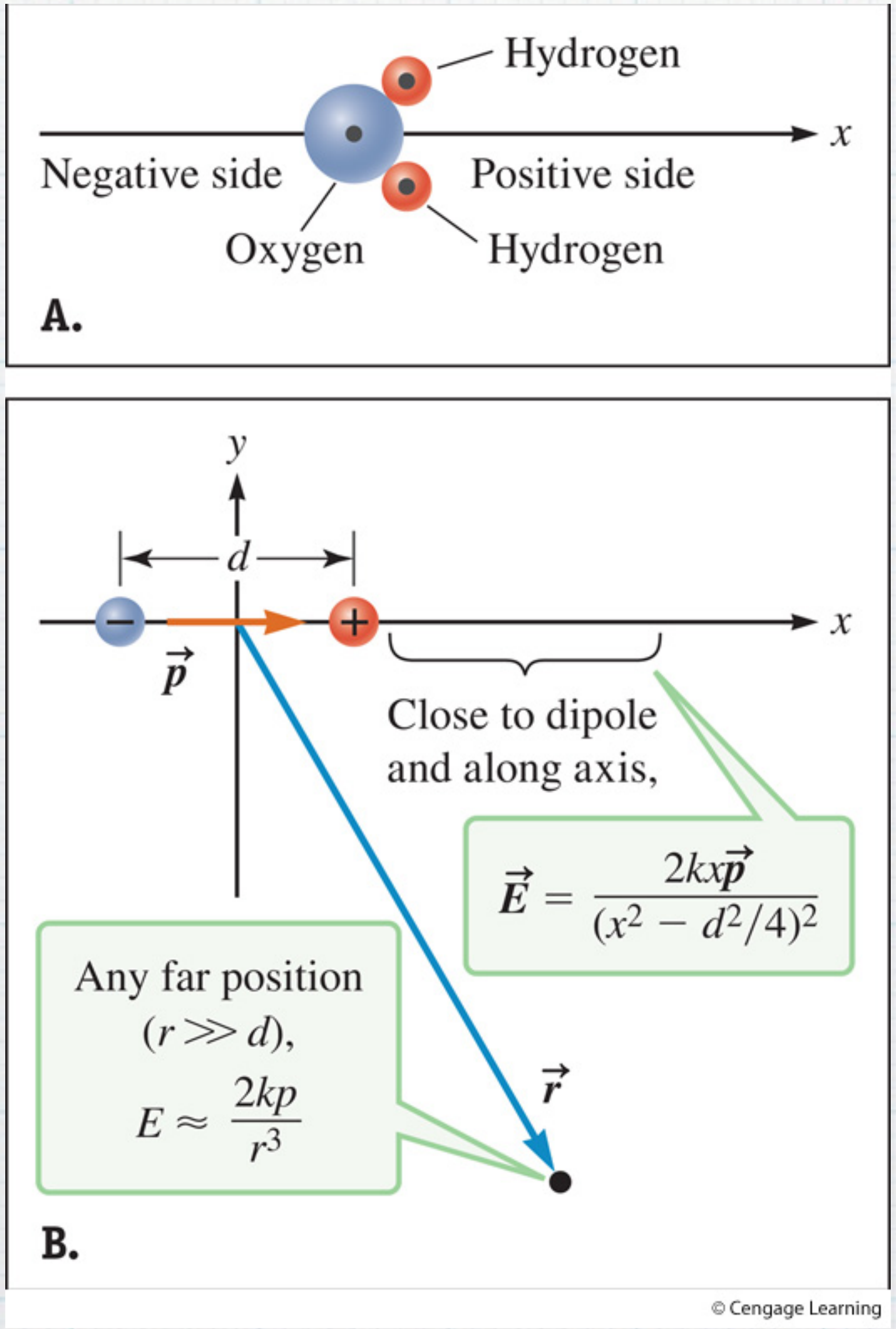
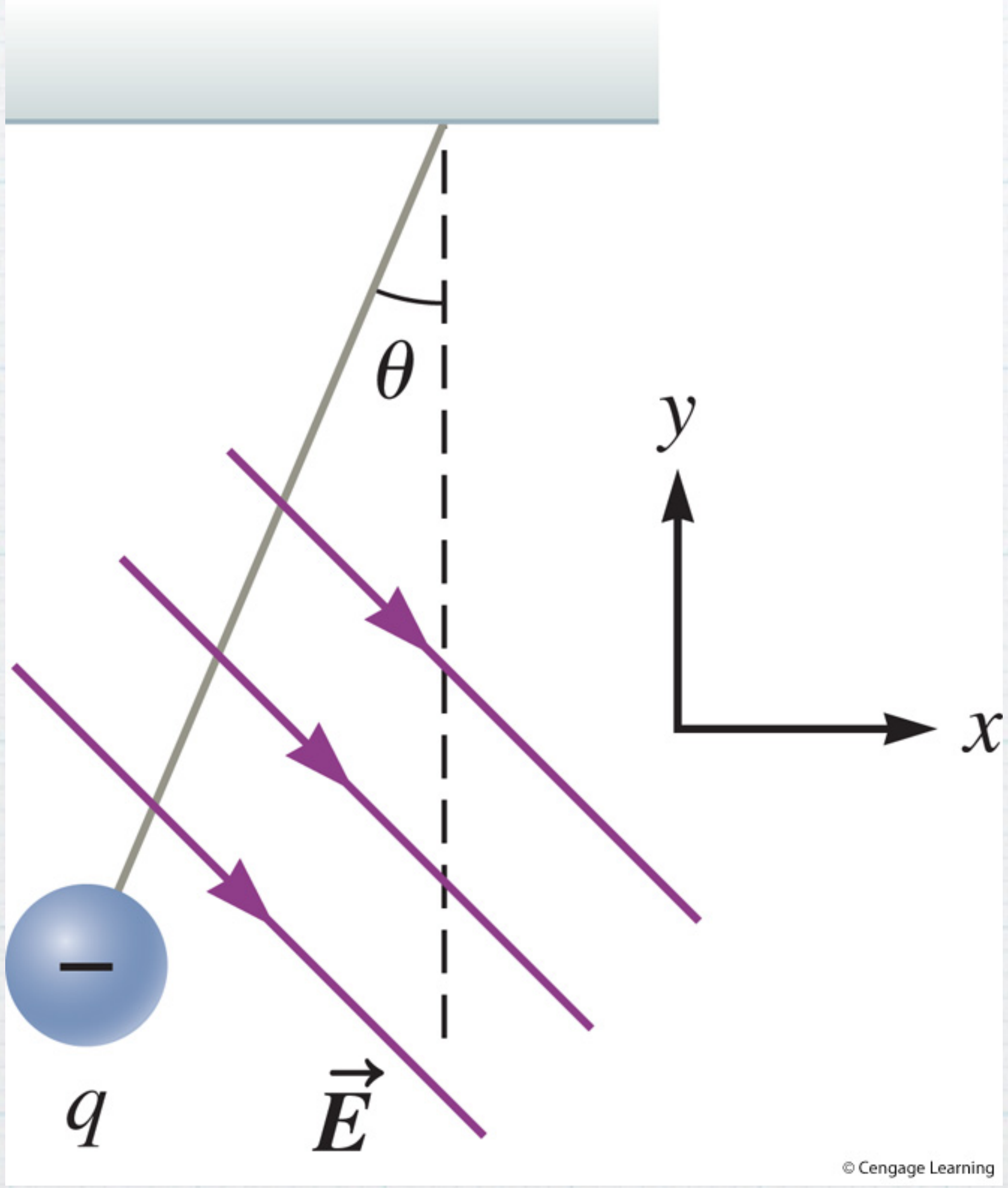
Far field approximation



$$|\vec{p}| = qd$$

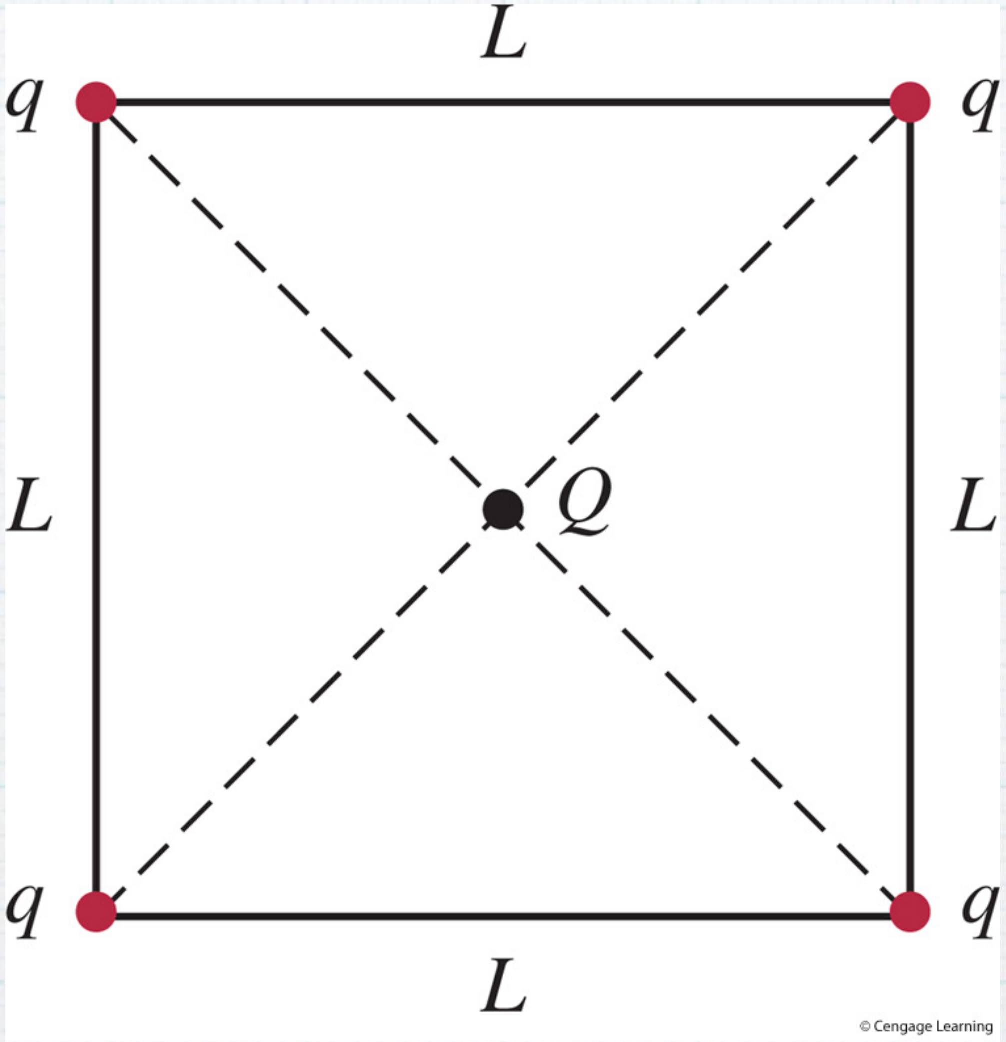
Charged particle in an electric field

$$\vec{F}_e = q_{test}\vec{E} = m_{test}\vec{a}_{test}$$

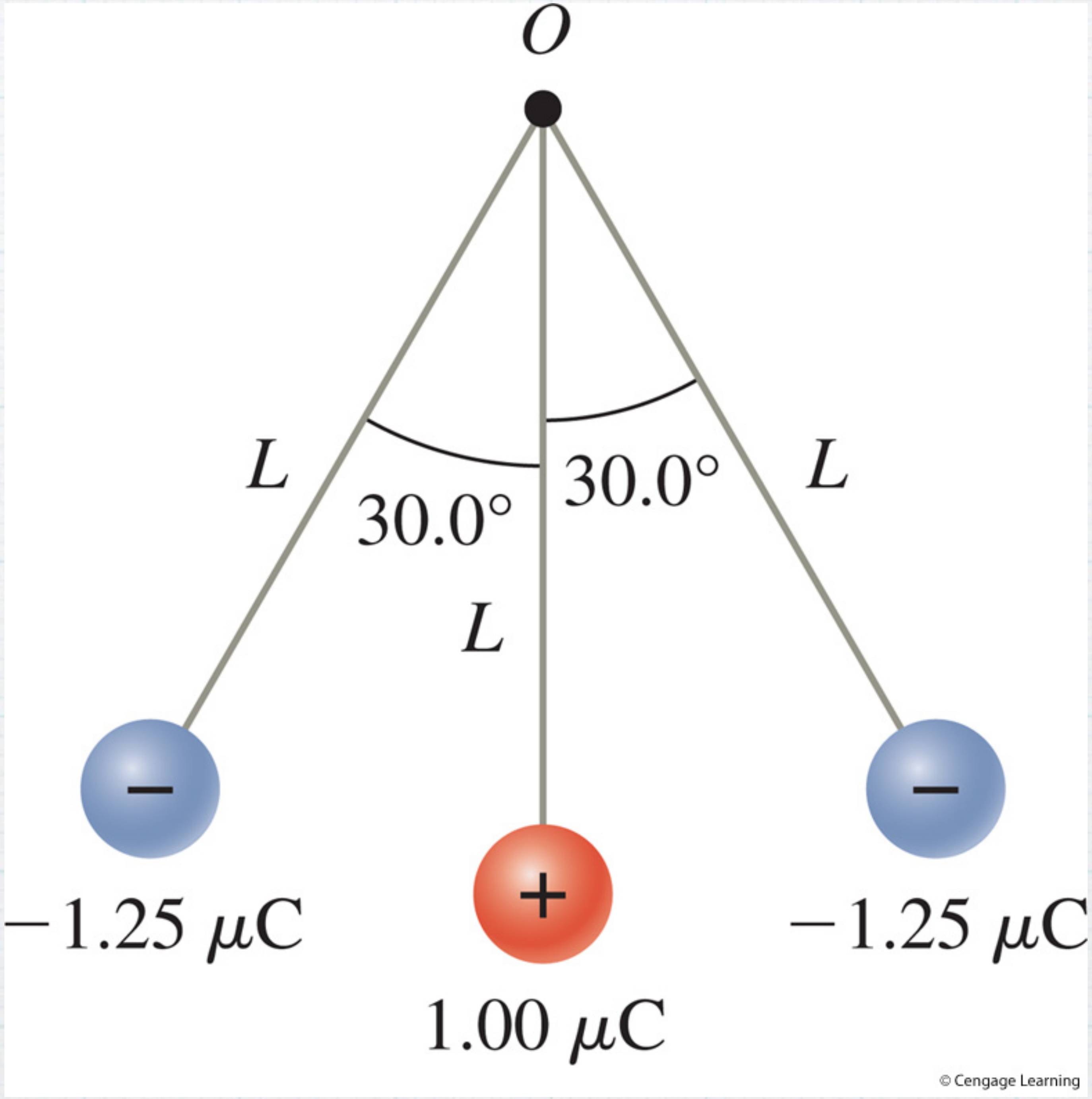


problem 53

We cut the string
what is the acceleration



again


O
L
30.0°
30.0°
L
L
−1.25 μC
−1.25 μC
1.00 μC
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Electric field from a continuous charge distribution

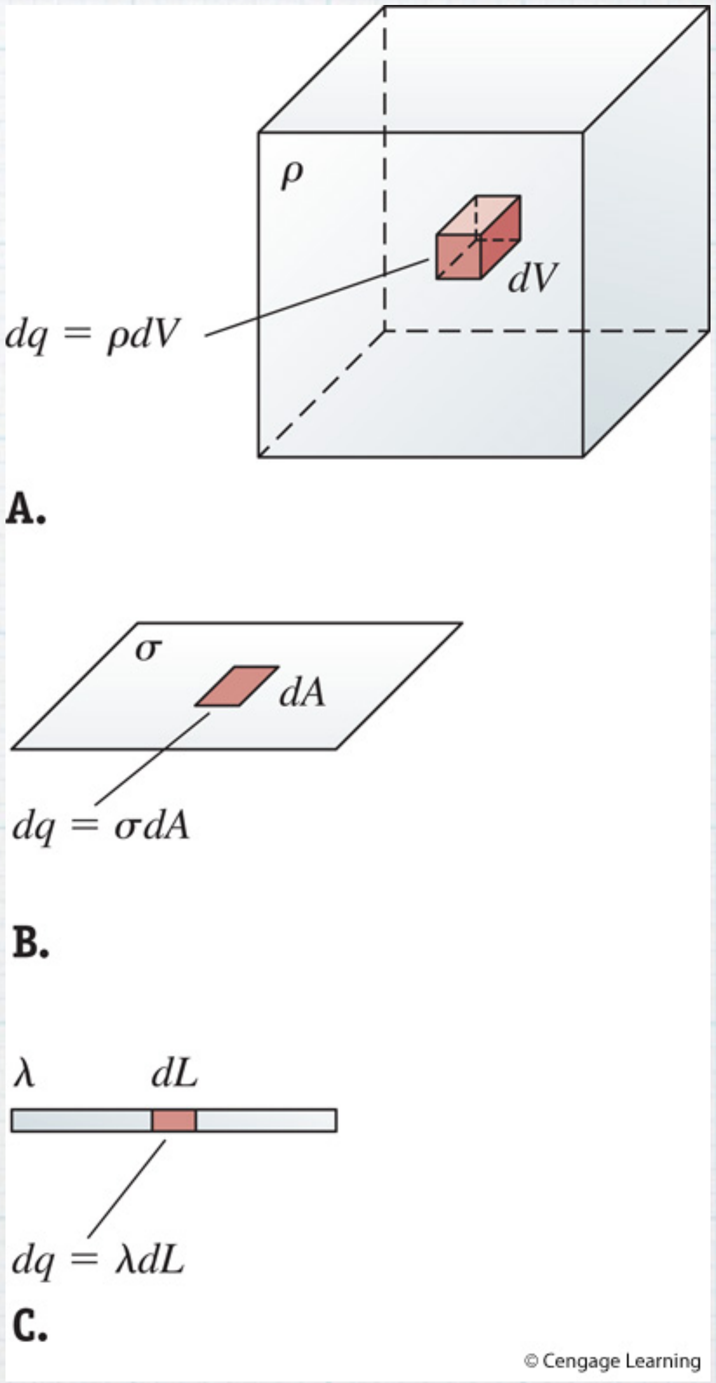
$$\rho = \frac{Q}{v} \rightarrow dq = \rho dv$$

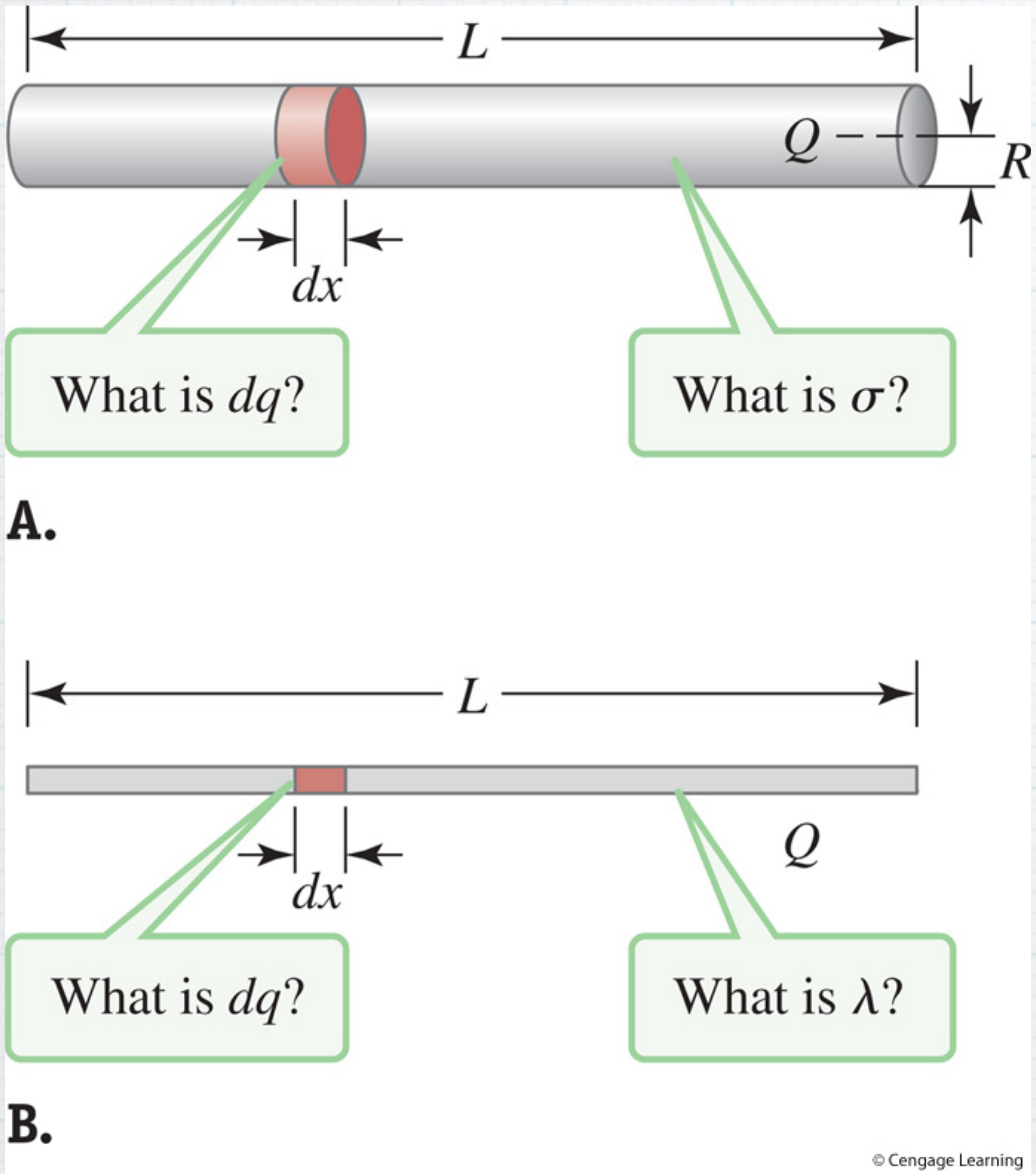
$$\sigma = \frac{Q}{A} \rightarrow dq = \sigma dA$$

$$\lambda = \frac{Q}{L} \rightarrow dq = \lambda dl$$

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

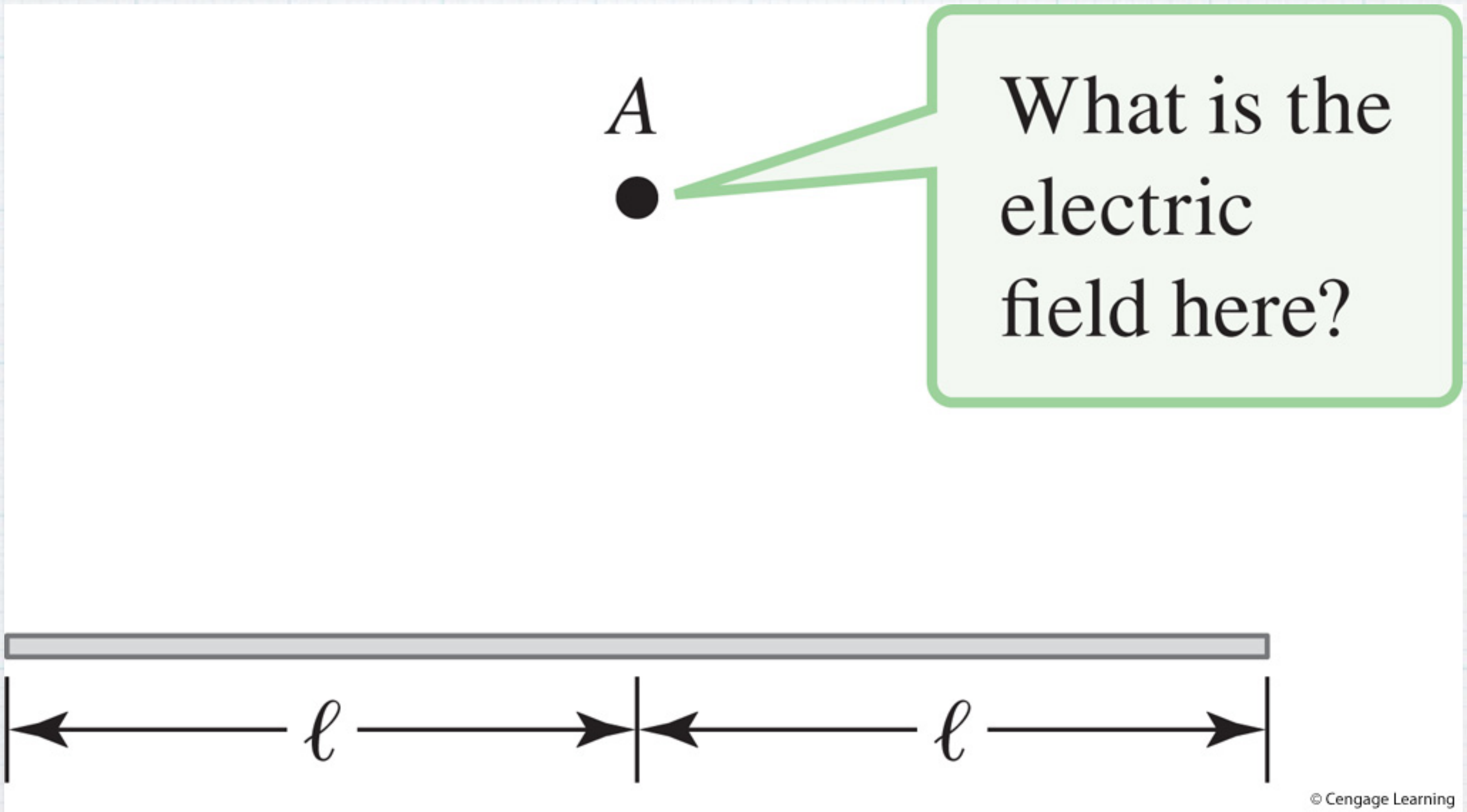
$$\vec{E} = k\int\frac{dq}{r^2}\hat{r}$$





Charge distributed only on surface

Charge on length


A
What is the electric field here?
ℓ
ℓ
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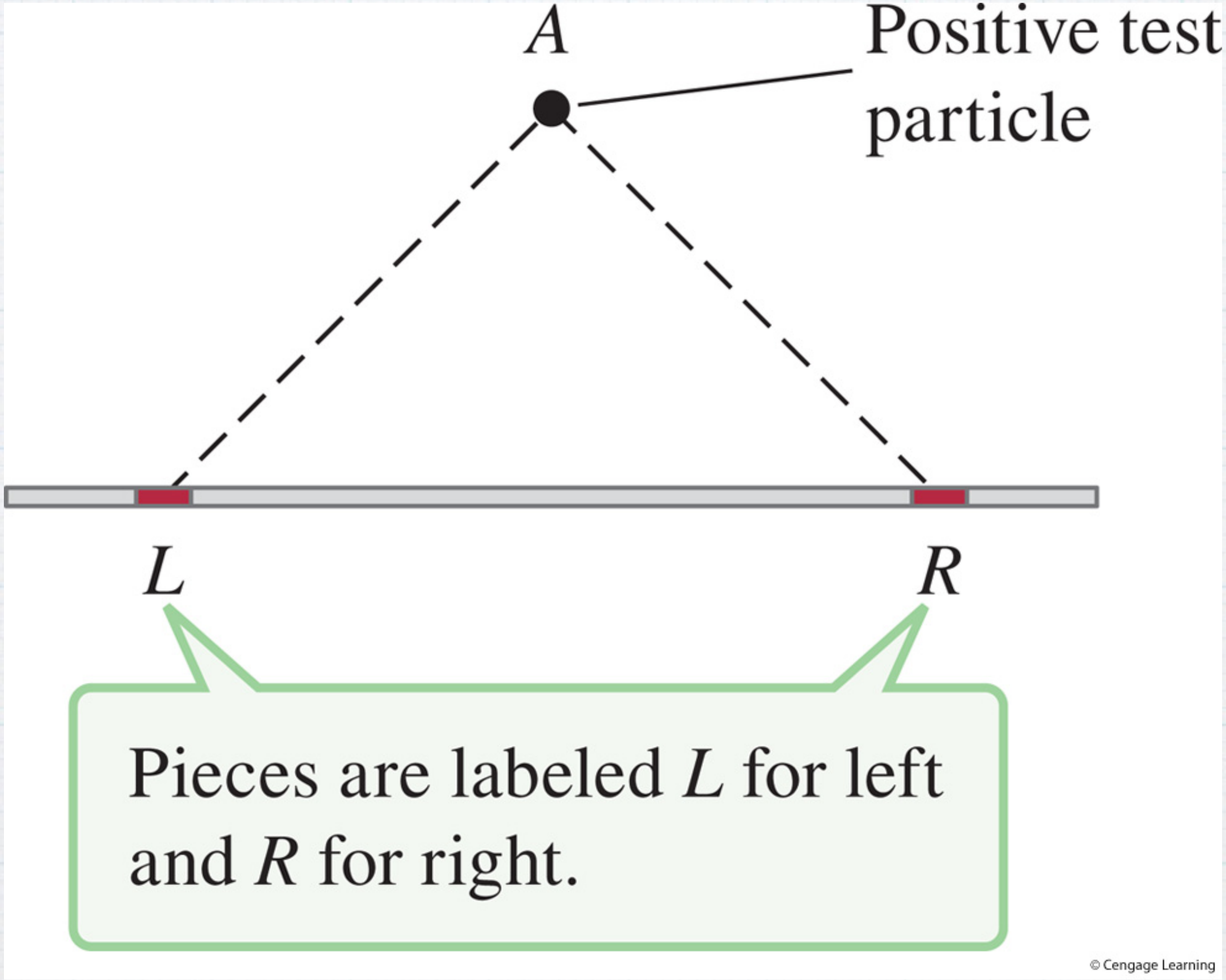
A
Positive test particle
L
R
Pieces are labeled L for left and R for right.
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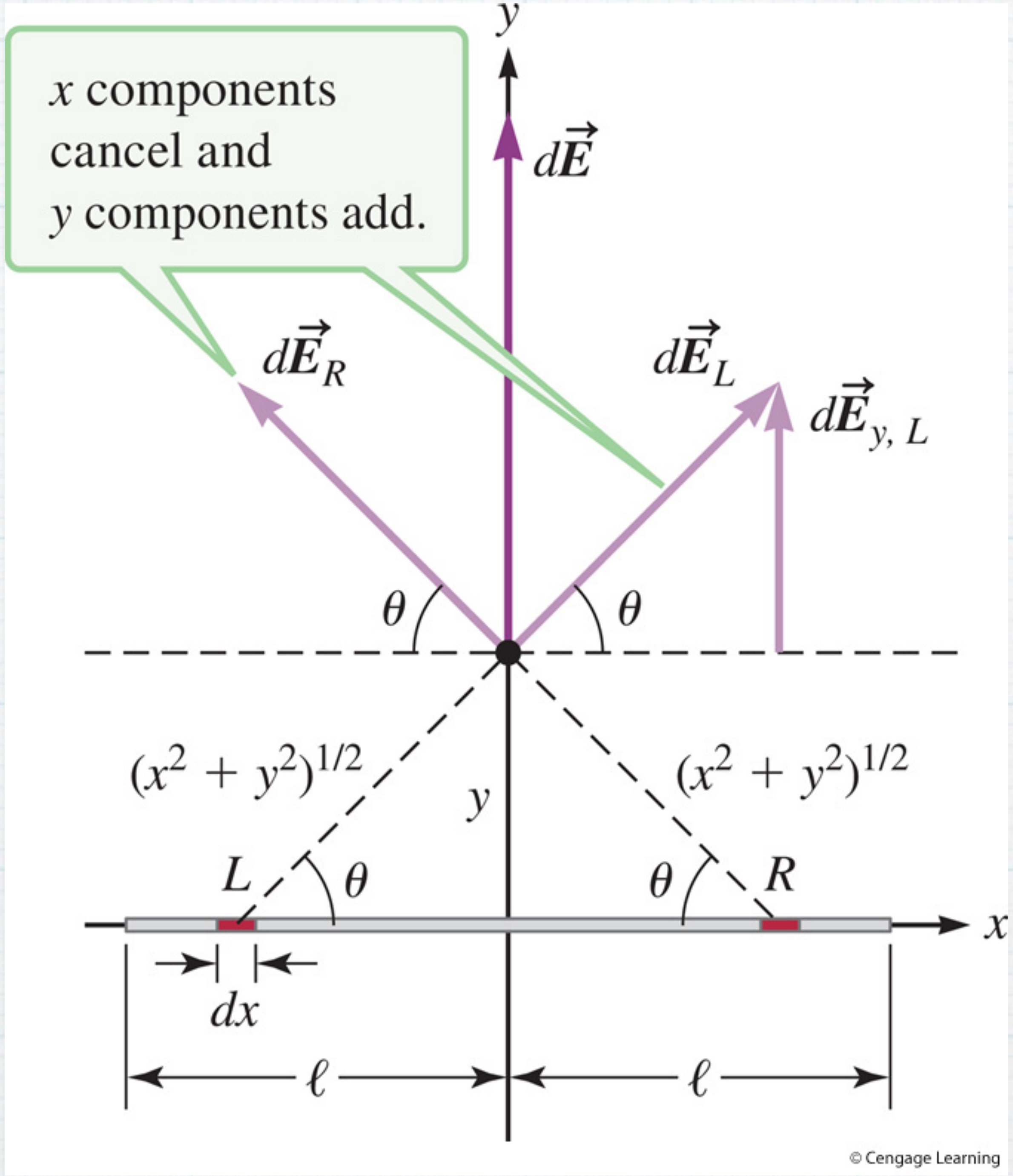
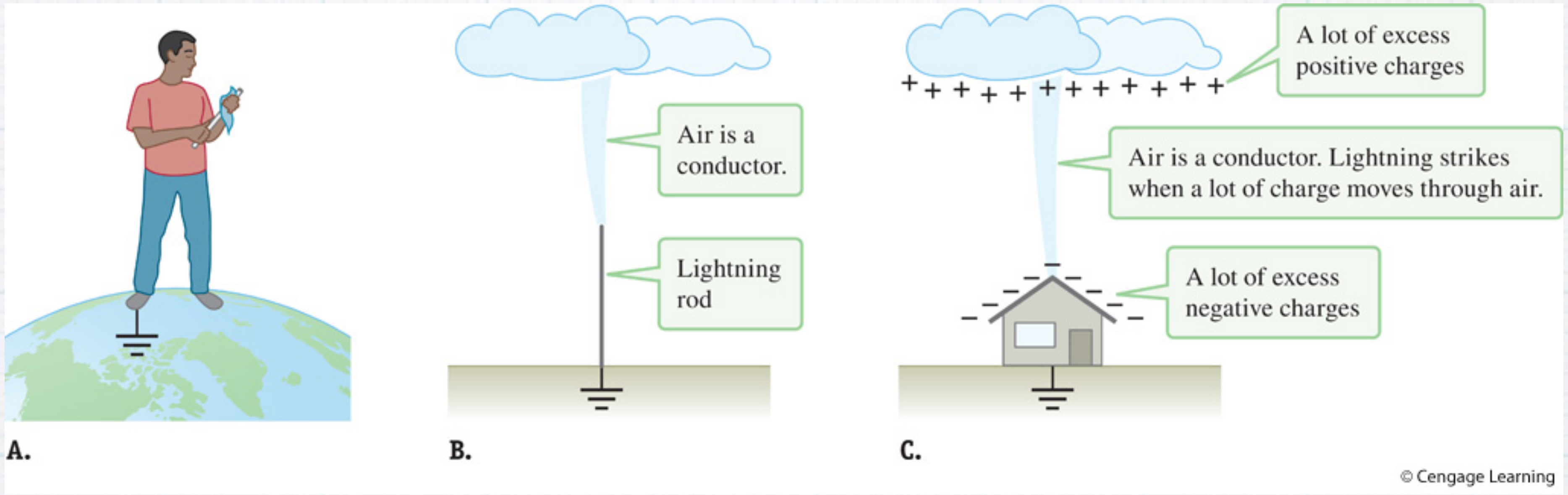
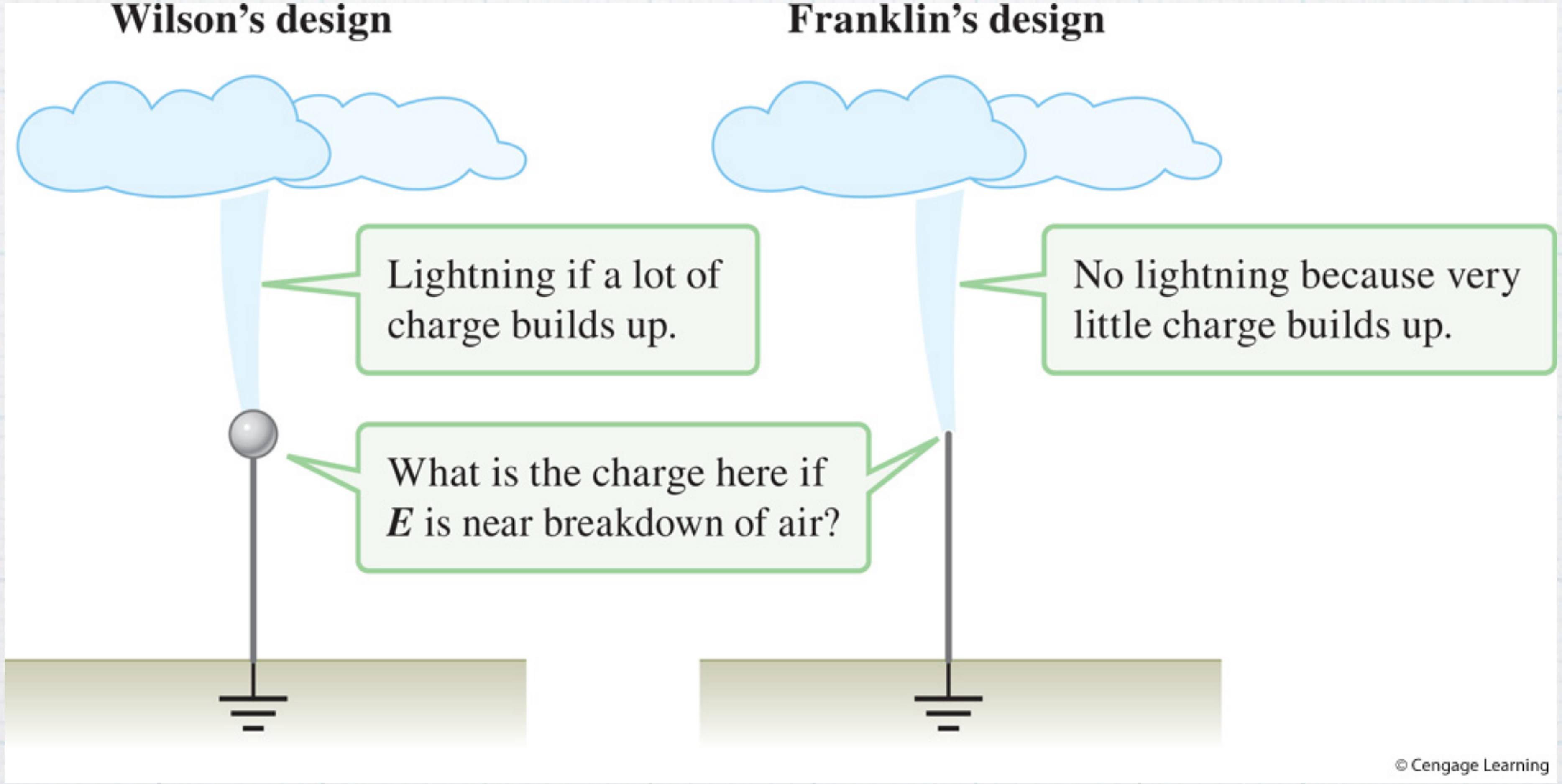


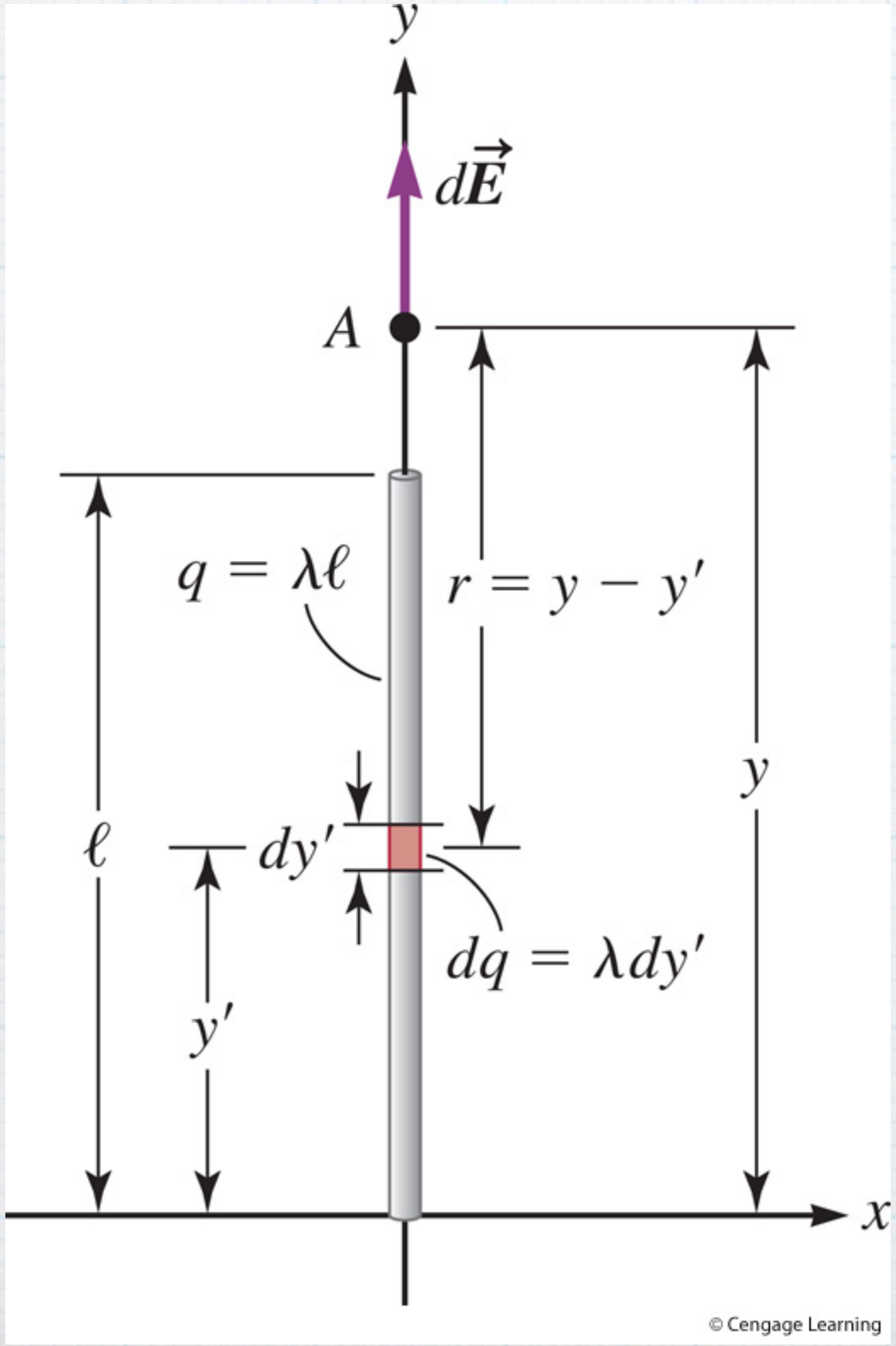
$$\vec{E}(y) = \frac{kQ}{y}\frac{1}{(l^2 + x^2)^{1/2}}\hat{j}$$

Lightning rod



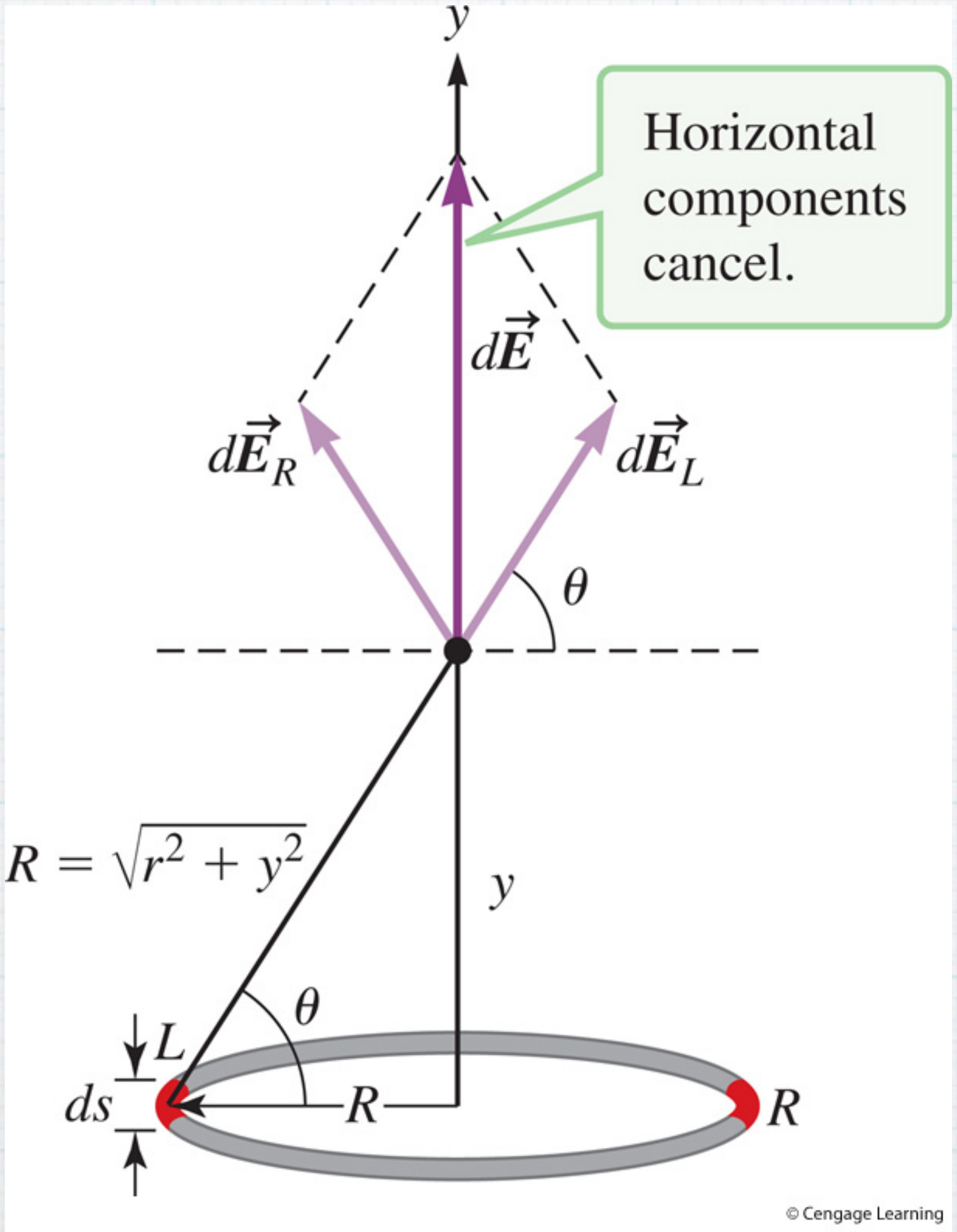


Wilson's lightning ball $\vec{E}(r) = k\frac{Q}{r^2}\hat{r}$

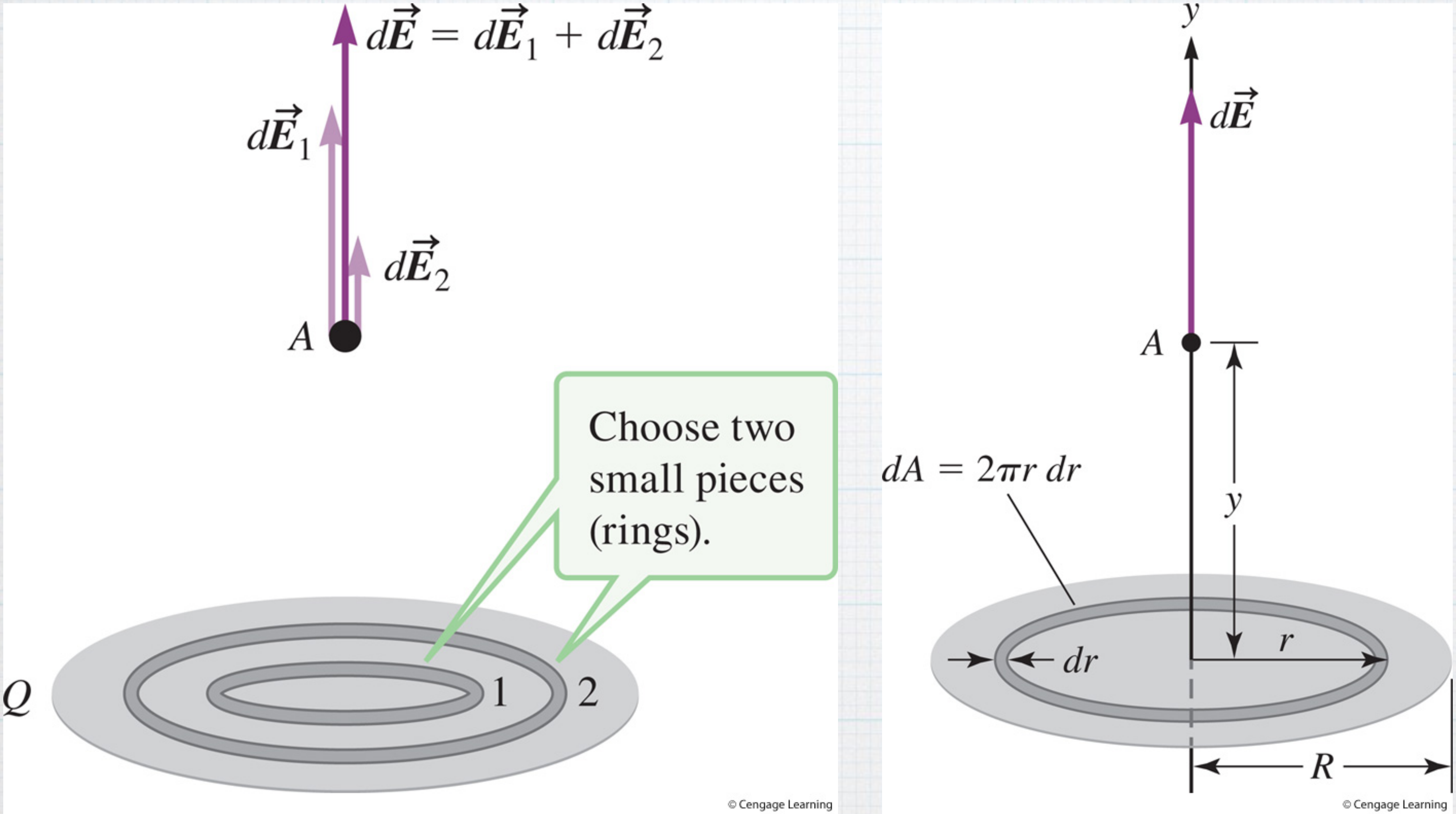


Franklin's lightning rod

$$\vec{E}(y) = \frac{kq}{(y(y-l))}\hat{j}$$

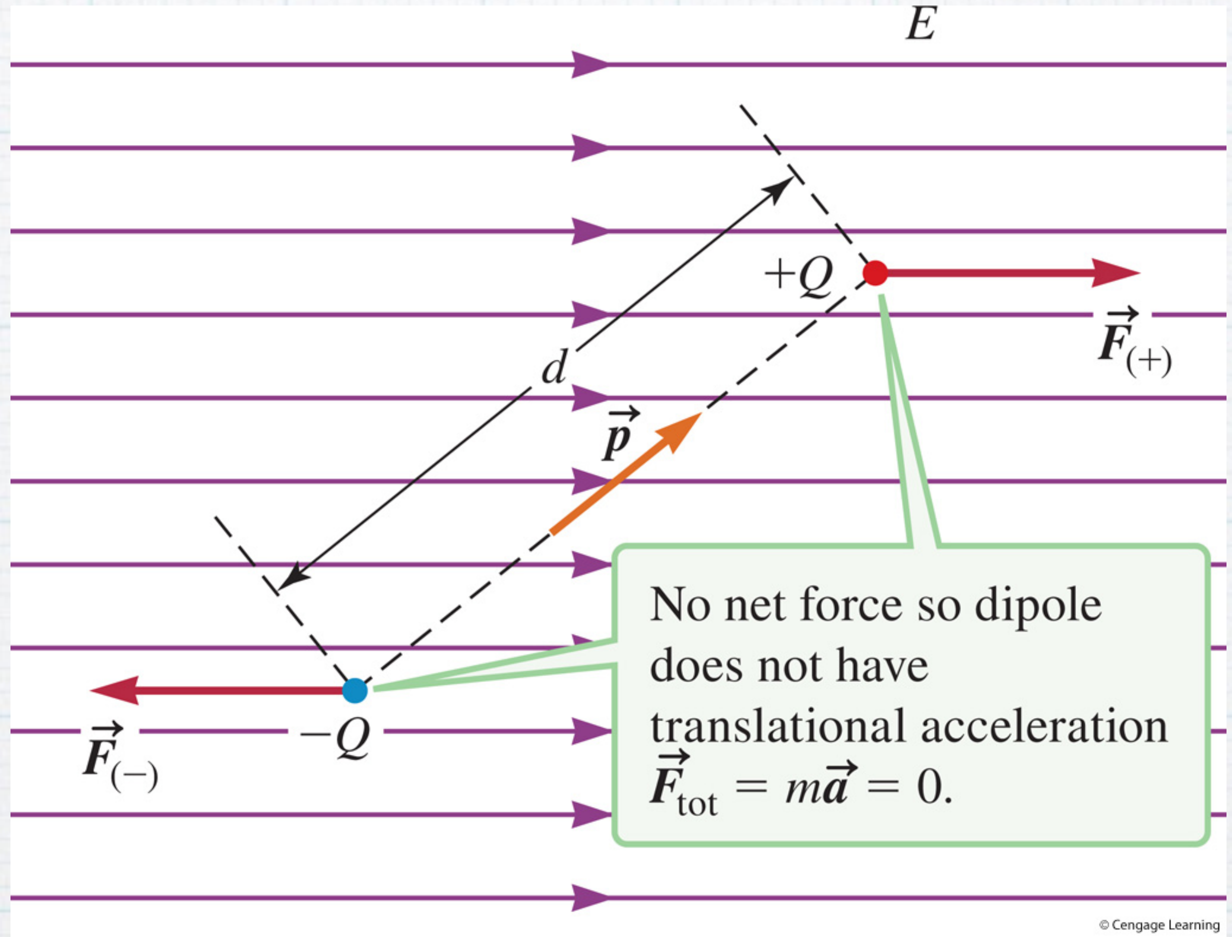


$$\vec{E}(y) = \frac{kQ}{(y^2 + R^2)^{3/2}}\hat{j}$$

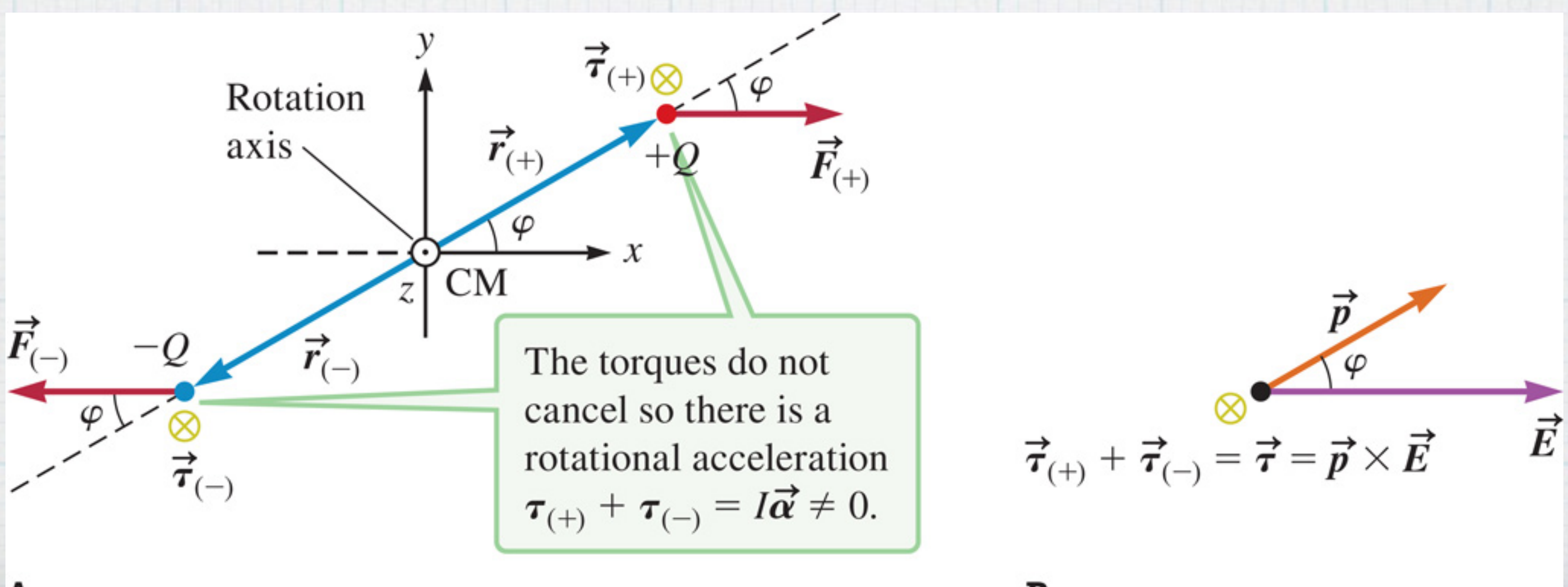


$$\vec{E}(y) = 2\pi k\sigma[1 - \frac{y}{(y^2+R^2)^{1/2}}]\hat{j}$$

More dipole moment stuff

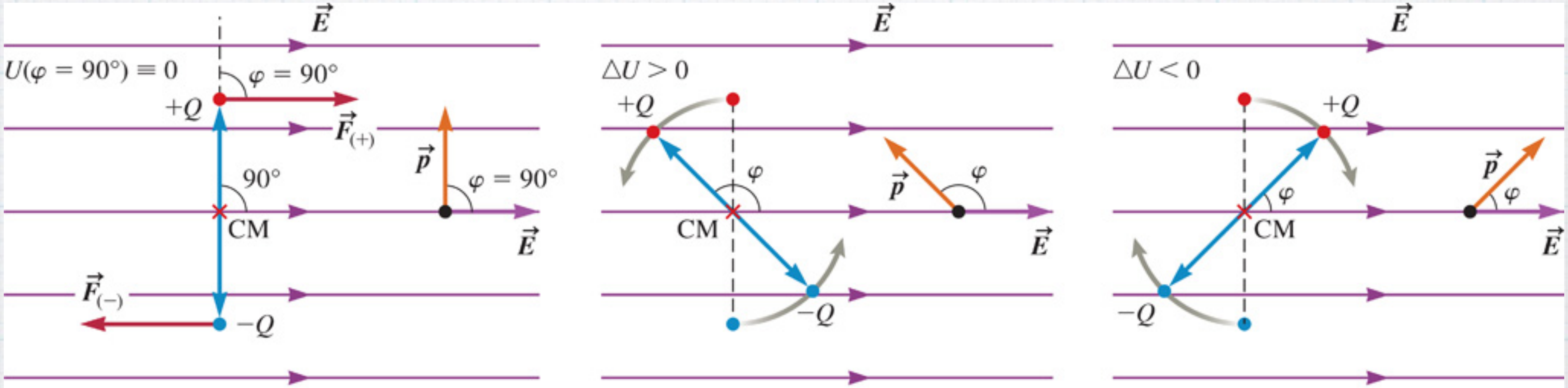


$$\vec{\tau} = \vec{p} \times \vec{E}$$



This is how your microwave works

$$U = -\vec{p} \cdot \vec{E}$$



A. Reference configuration **B.** Potential energy increases. **C.** Potential energy decreases.