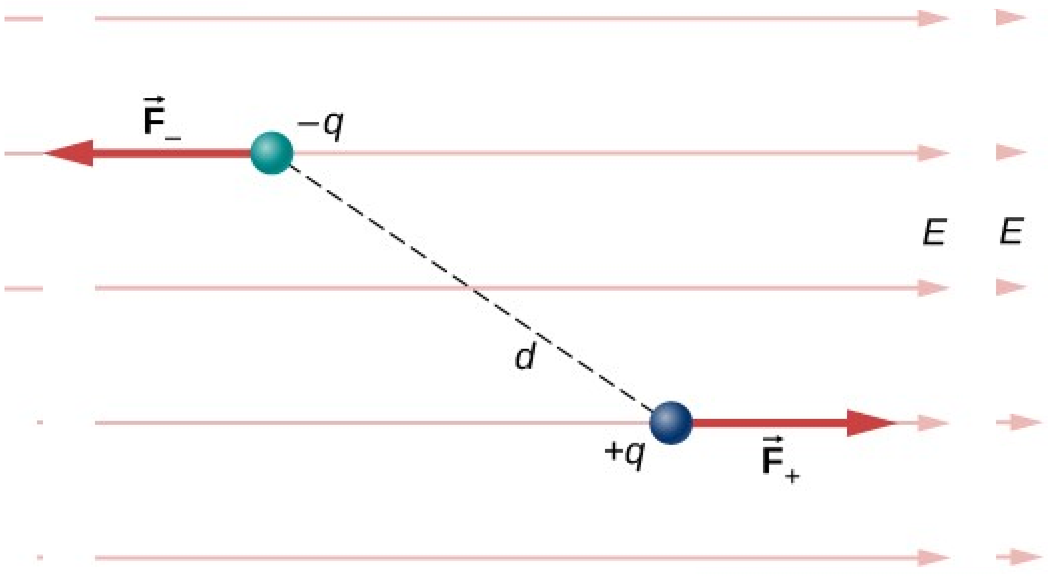
Electric Dipoles

Two opposite charges are connected by a rigid rod.
It is in a uniform electric field that points to the right.
How do you expect this dipole to move?



A. move right

B. move left

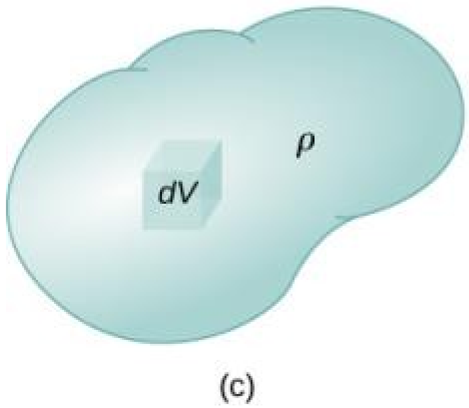
C. rotate clockwise

D. rotate counterclockwise

E. remain at rest

Electric Field of a Charge Distribution

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r} \qquad \text{(electric field of a point charge)}$$



- break up the charge into little parts, each with charge dq
- each dq contributes a field of $d\vec{E}$ at the point *P*
- add up all the contributions to find the total field

$$\vec{E} = \int d\vec{E} = \int \frac{1}{4\pi\epsilon_0}\frac{dq}{r^2}\hat{r}$$

Electric Field of a Charge Distribution

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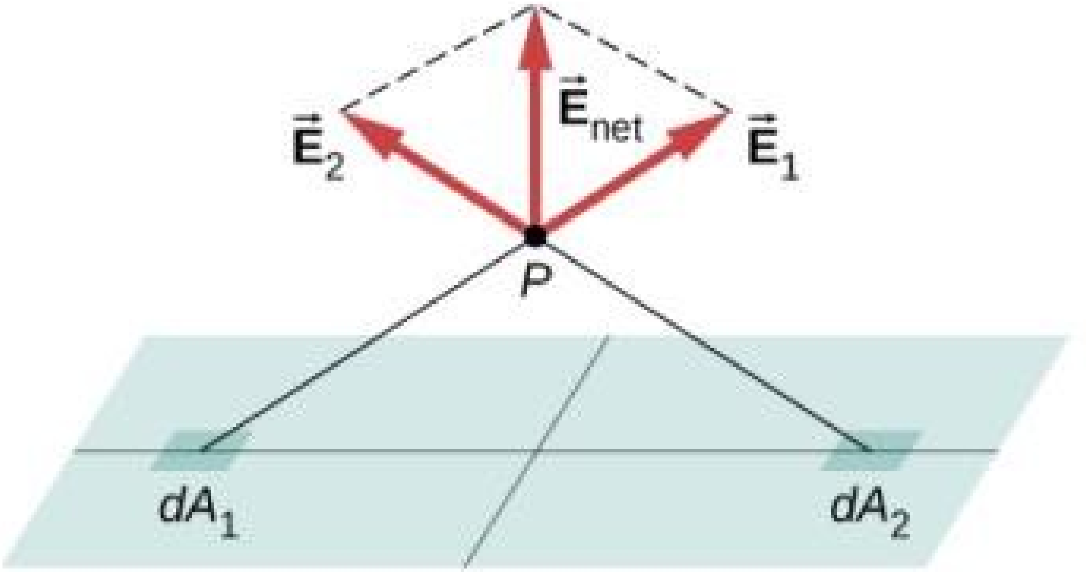
Look for symmetry to simplify the problem.

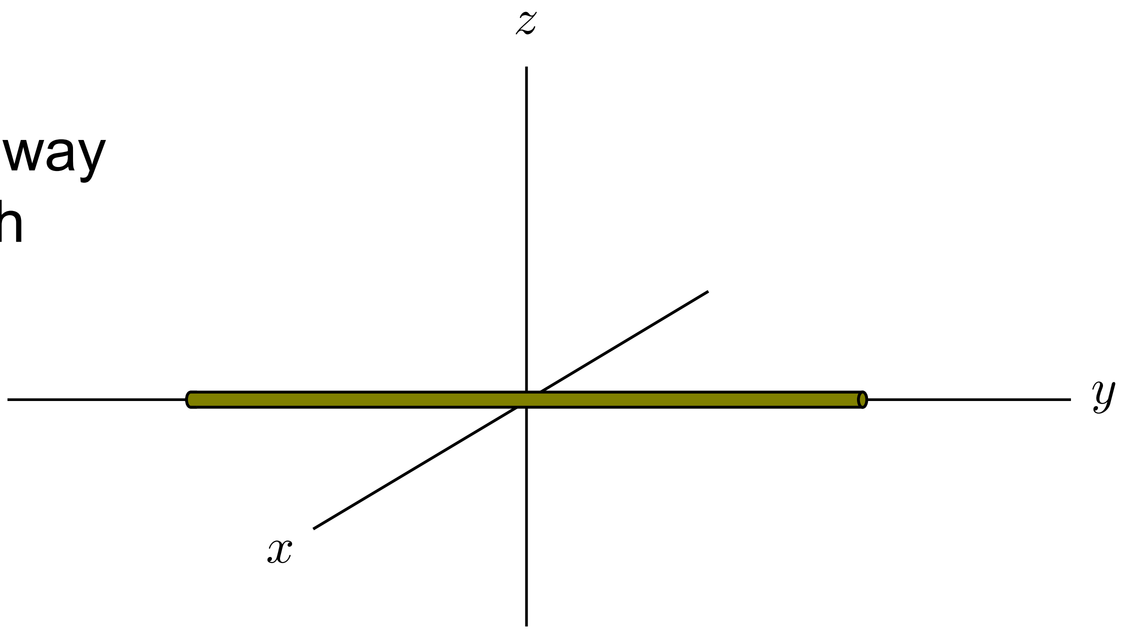


Electric Field of a Charge Distribution

$$\vec{E} = \int d\vec{E} = \int \frac{1}{4\pi\epsilon_0}\frac{dq}{r^2}\hat{r}$$

Find the electric field a distance z away from the center of a line charge (with charge density λ C/m).

(you may consult a table of integrals or Wolfram Alpha)



$$\vec{E}(P) = \frac{1}{4\pi\epsilon_0}\frac{Q}{z\sqrt{z^2+(L/2)^2}}\hat{k}$$

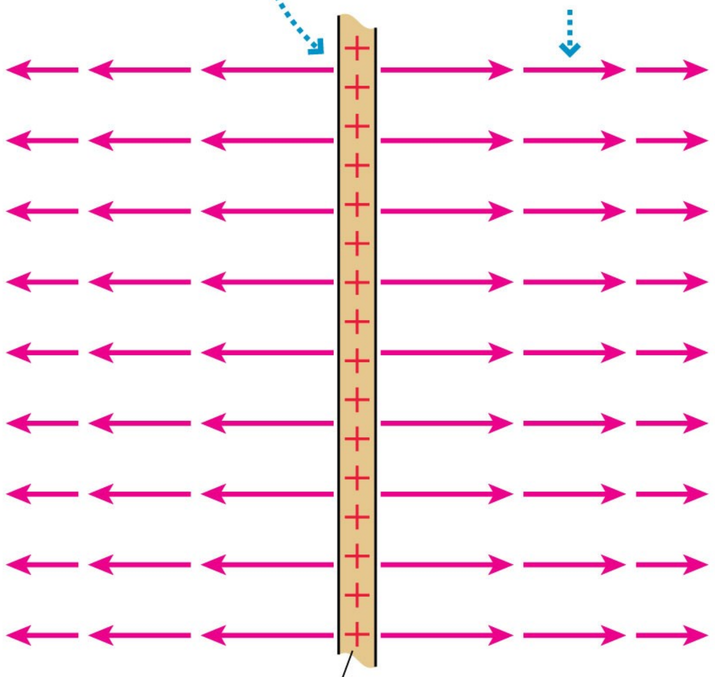
Check limits:

$z \ll L \qquad z \gg L$

Electric Field of a Charge Distribution

For an ***infinite*** line charge

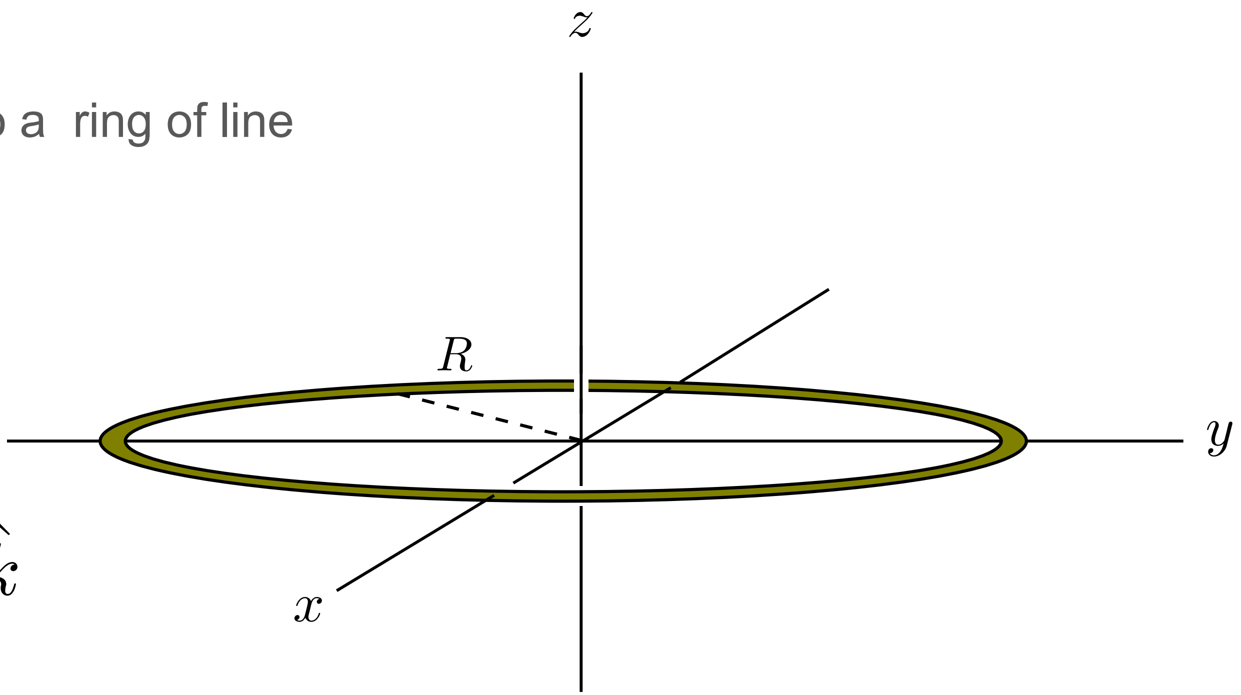
$$\vec{E}_{\text{line}} = \left(\frac{1}{4\pi\epsilon_0} \frac{2|\lambda|}{r}, \begin{cases} \text{away from line if charge } + \\ \text{toward line if charge } - \end{cases} \right)$$



Electric Field of a Charge Distribution

$$\vec{E} = \int d\vec{E} = \int \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2} \hat{r}$$

Find the field along the z axis due to a ring of line charge (charge density λ C/m)



$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{zQ}{(z^2 + R^2)^{3/2}} \hat{k}$$

Electric Field of a Charge Distribution

$$\vec{E} = \int d\vec{E} = \int \frac{1}{4\pi\epsilon_0}\frac{dq}{r^2}\hat{r}$$

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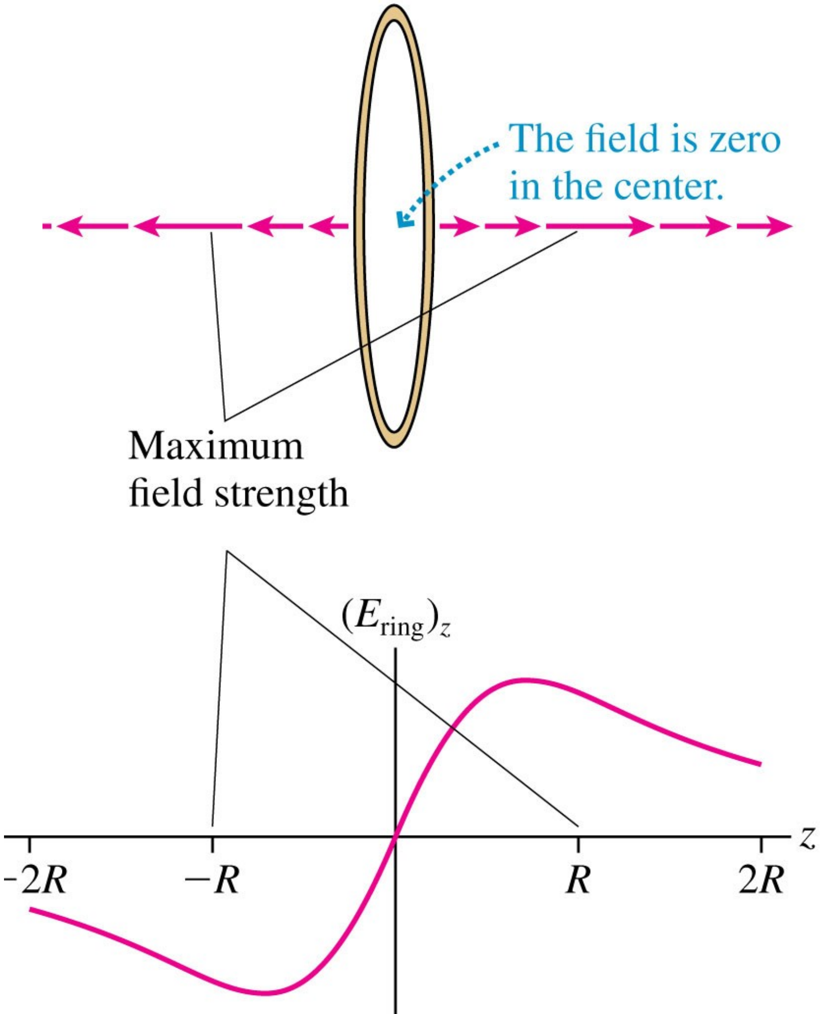
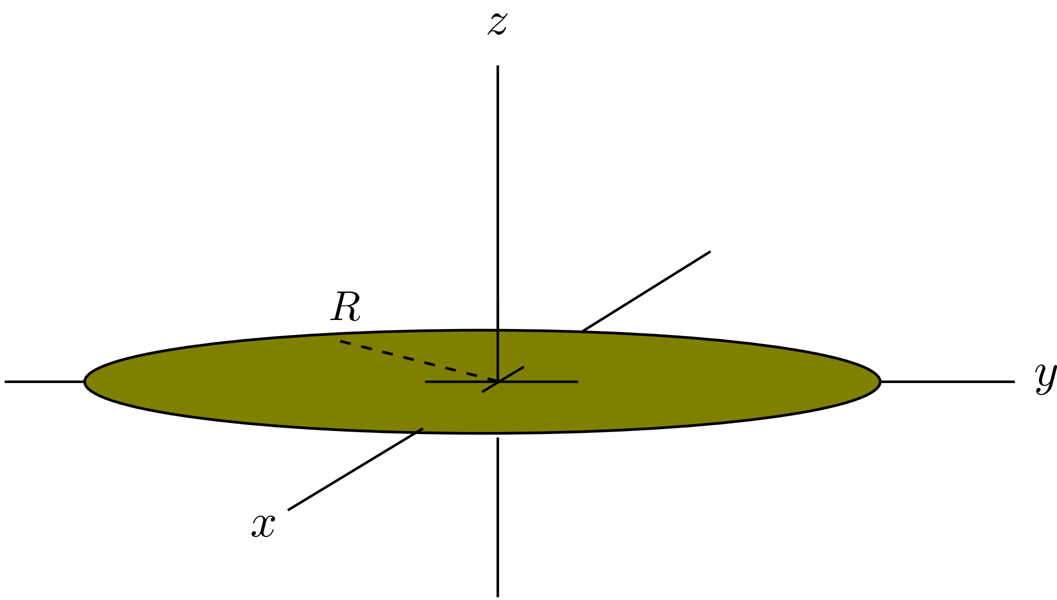


Electric Field of a Charge Distribution

$$\vec{E} = \int d\vec{E} = \int \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2} \hat{r}$$

Find the field along the z axis due to a disk of surface charge (charge density σ C/m^2)



$$\vec{E} = \frac{\sigma}{2\epsilon_0} \left(1 - \frac{z}{\sqrt{z^2 + R^2}} \right) \hat{k}$$

Check limits:

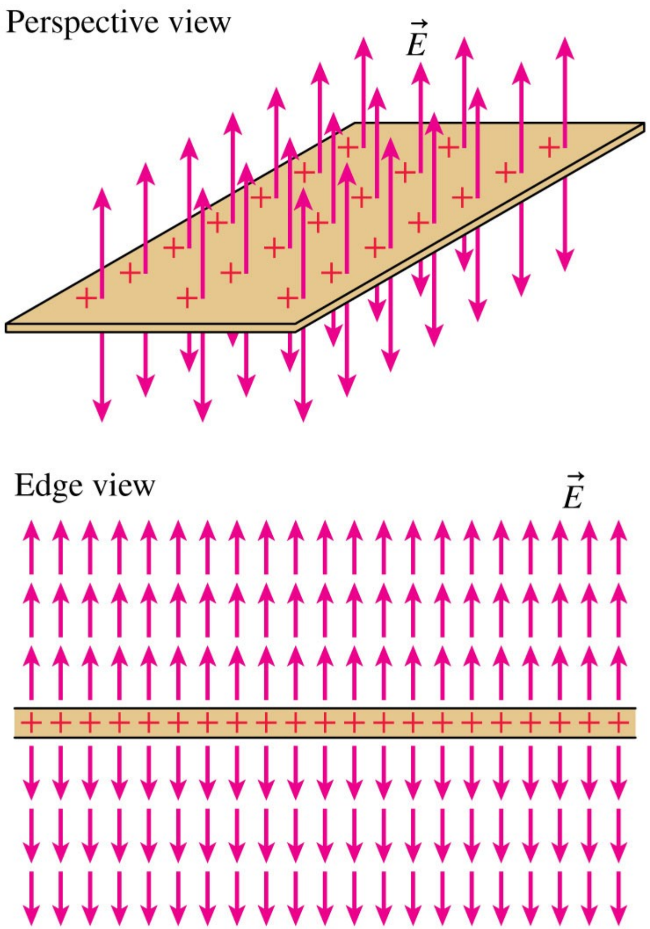
$z \ll R$ $z \gg R$

Electric Field of a Charge Distribution

Example: infinite plane charge

charge density σ C/m^2

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



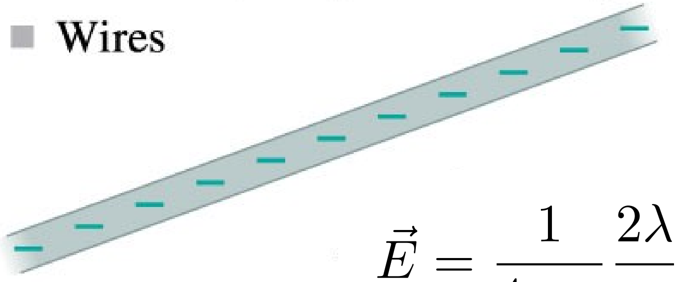
Electric Field of a Charge Distribution

Four key electric fields:

A point charge:
- Small charged objects

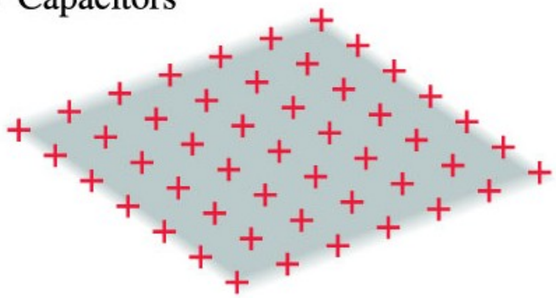
$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$

An infinitely long line of charge:
- Wires



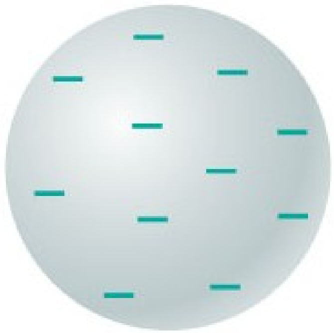
$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{2\lambda}{r}\hat{r}$$

An infinitely wide plane of charge:
- Capacitors



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

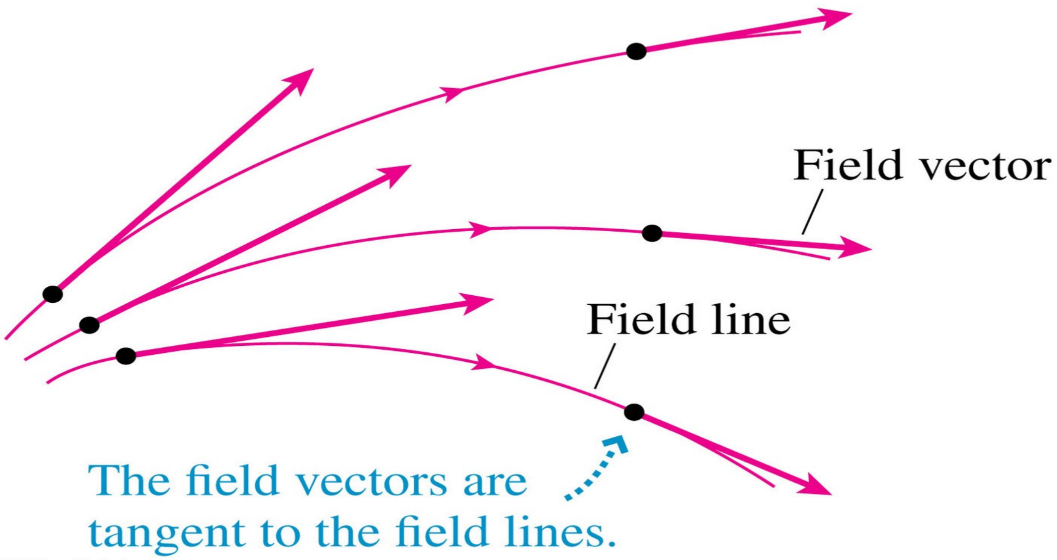
A sphere of charge:
- Electrodes



$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\hat{r}$$

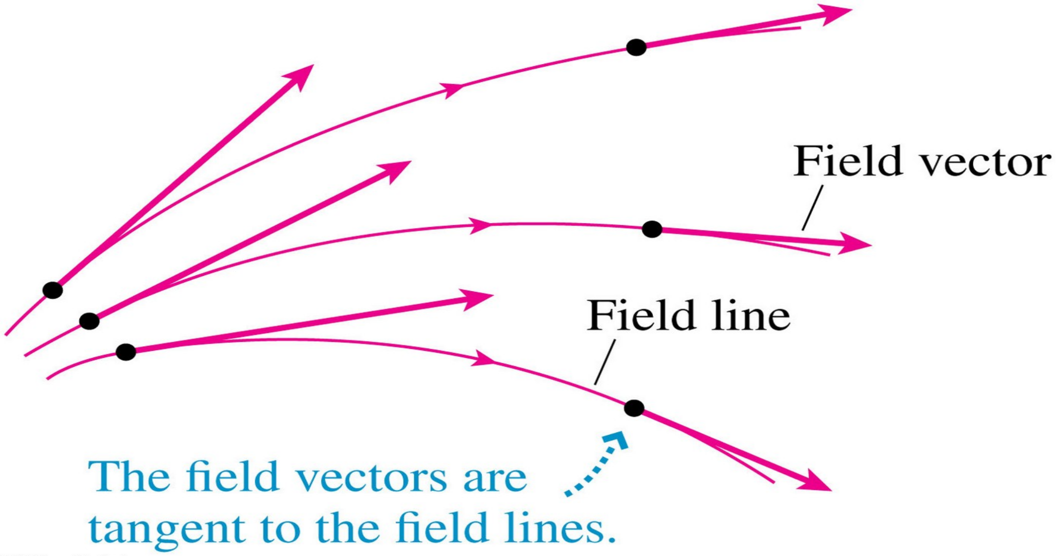
$$(r > R)$$

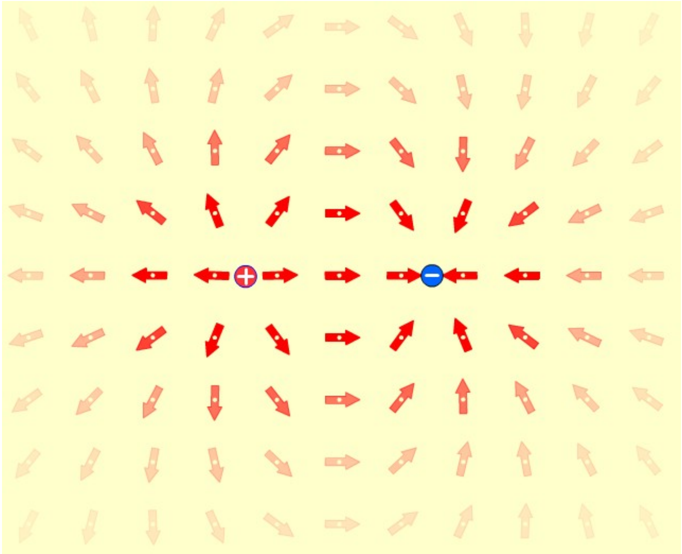
Electric Field Lines

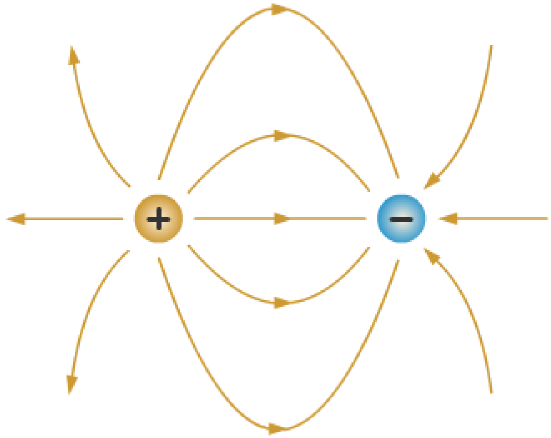


- Electric field lines are *continuous* curves tangent to the electric field vectors.
- Closely spaced field lines indicate a greater field strength.
- Electric field lines start on positive charges and end on negative charges.
- Electric field lines never cross.

Electric Field Lines







Electric Field of a Point Charge

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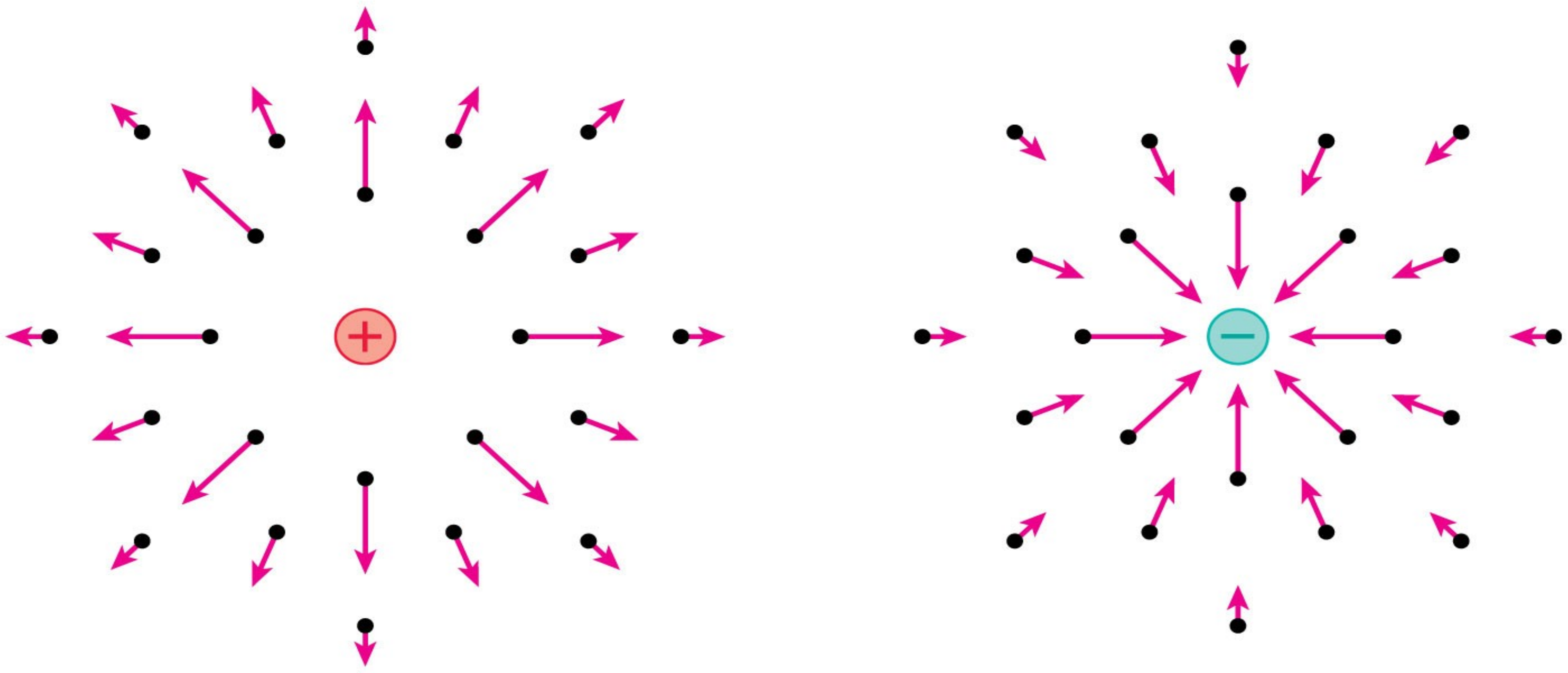

Electric Field Lines

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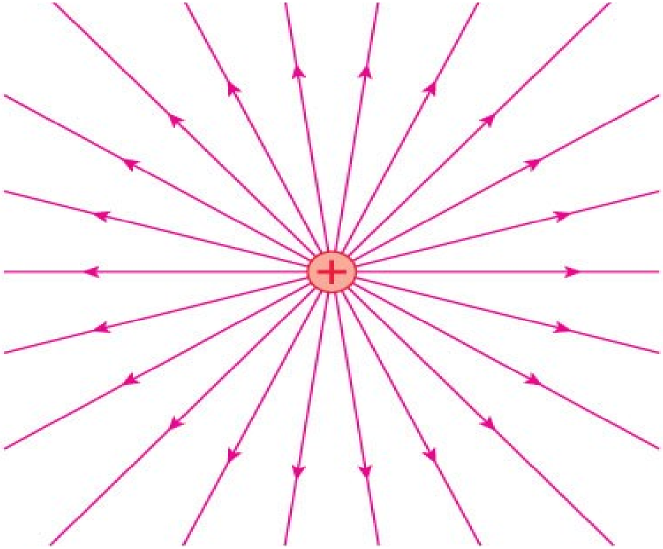
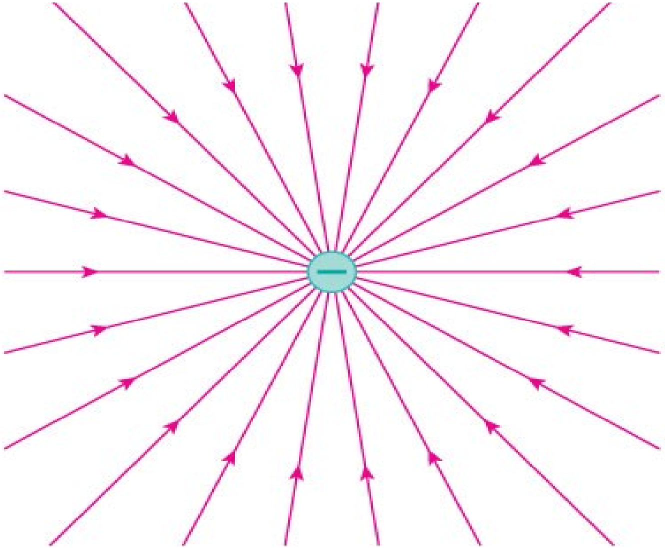
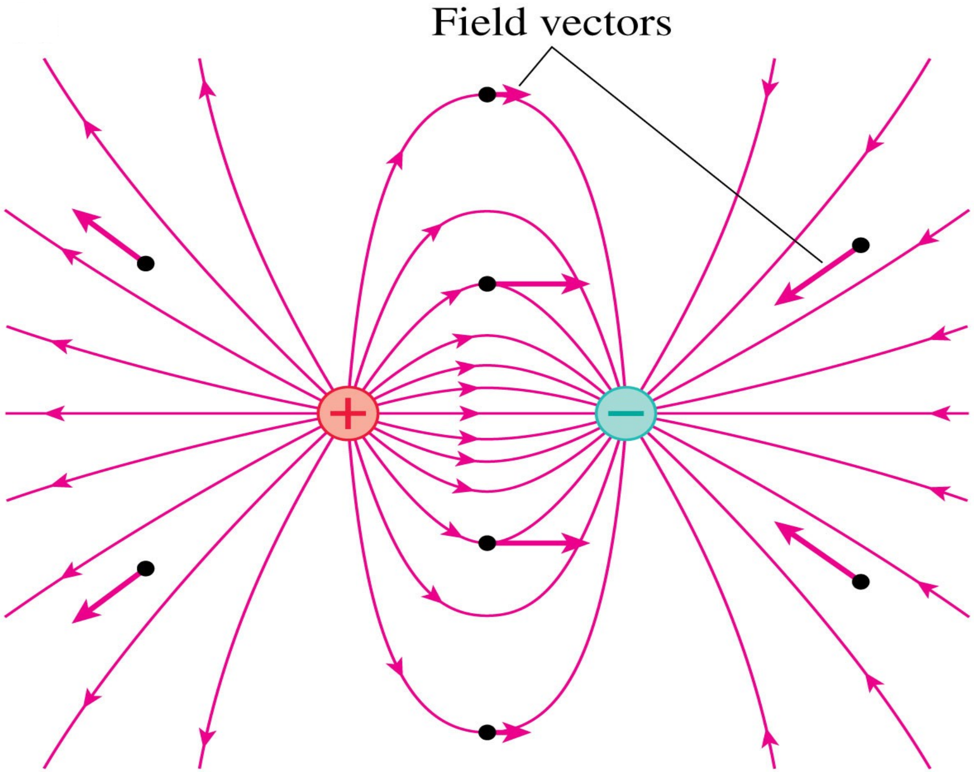




Electric Field Lines

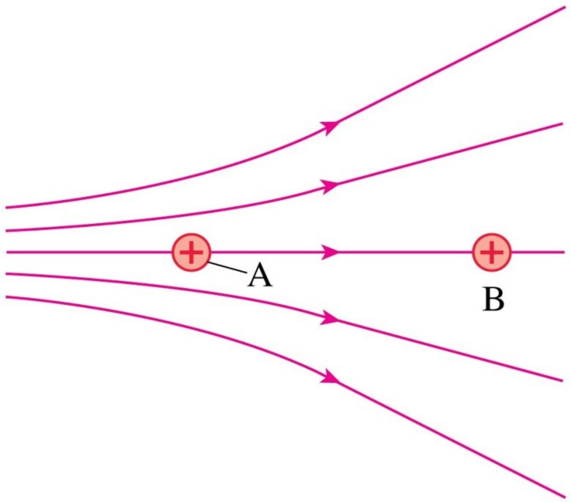


See field line simulator

Electric Field Lines

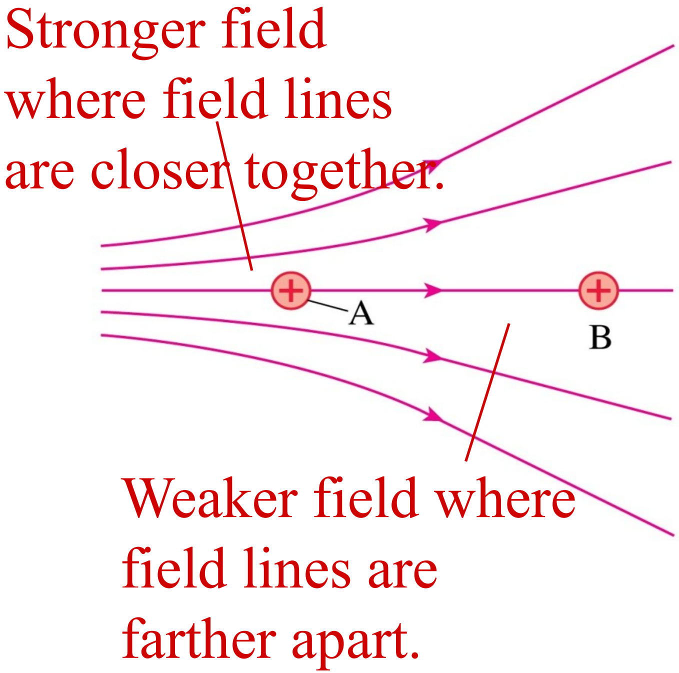
Two protons, A and B, are in an electric field. Which proton has the larger acceleration?

A. Proton A
B. Proton B
C. Both have the same acceleration.



Electric Field Lines

Two protons, A and B, are in an electric field. Which proton has the larger acceleration?



✔ **A. Proton A**

B. Proton B

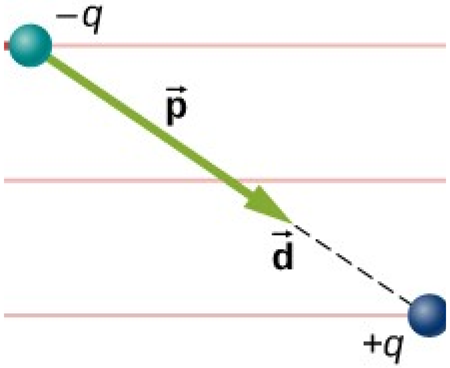
C. Both have the same acceleration.

Electric Dipoles

A dipole moment is defined as

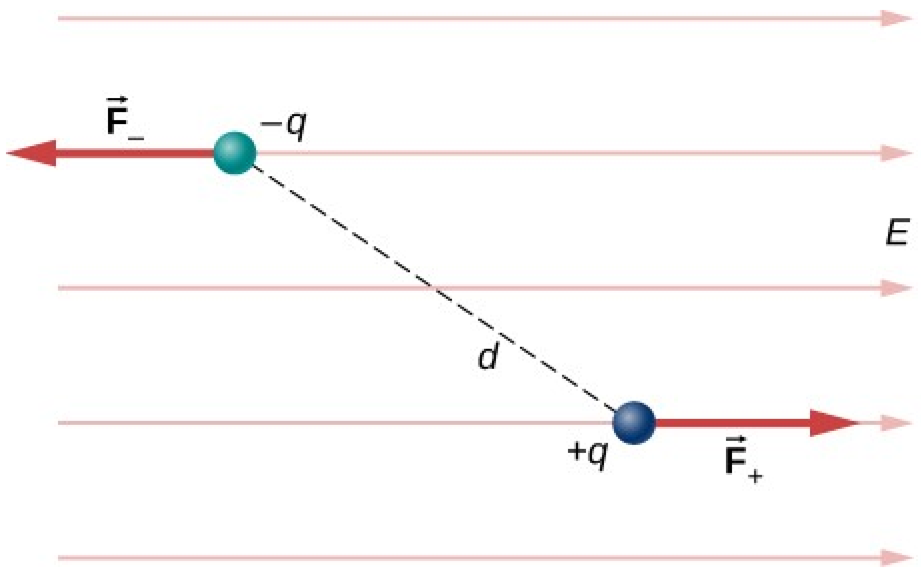
$$\vec{p} = q\vec{d}$$

It points from the negative to the positive charge.



Electric Dipoles

A dipole moment experiences a torque in an electric field.



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